Pre-Diversion Root River Data Collection Summary

Prepared For:

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Acronyms and Abbreviations

µg/L	microgram(s) per liter
cfs	cubic foot/feet per second
CH2M	CH2M HILL, Inc.
City	City of Waukesha
CPUE	catch per unit effort
DELT	deformities, erosion, lesions, tumors
fps	foot/feet per second
HBI	Hilsenhoff Biotic Index
IBI	Index of Biotic Integrity for Warmwater Fish Communities
Jacobs	Jacobs Engineering Group Inc.
mg/L	milligram(s) per liter
MPTV	mean pollution tolerance value
mS/cm	microsiemens per centimeter
NTU	nephelometric turbidity units
QAPP	Quality Assurance Project Plan
S.U.	standard unit(s)
USGS	U.S. Geological Survey
WDNR	Wisconsin Department of Natural Resources

1 Background

The City of Waukesha, Wisconsin (City) transitioned to a Lake Michigan water supply in October 2023 consistent with the 2021 Diversion Approval granted by the Wisconsin Department of Natural Resources (WDNR). The Diversion Approval requires the City to monitor the Root River to assess the impact of the return flow wastewater discharge. The City also is required to report the Root River monitoring results and impact assessment annually.

In preparation for the diversion and assessing the impact that the diversion and return flow have on the Root River, the City implemented a voluntary pre-diversion data collection program. The data collection began in 2017 to provide pre-diversion baseline water quality, flow, habitat, macroinvertebrate, and fish data (CH2M 2017). The City completed its transition to Lake Michigan water and assessing impact from the return flow can be completed in the future. However, in preparation for the impact assessment, a summary of the pre-diversion monitoring (pre-October 2023) is provided here. Future annual reports will be completed in October through September timeframes and will include post-diversion conditions.

2 Return Flow Volume

The City constructed most of the return flow infrastructure in August 2023. At this time, return flow was intermittently pumped to the Root River for typical construction startup and testing procedures of the pump station, pipeline, and associated control programming, and to support a dye tracer study by the U.S. Geological Survey (USGS) for its area-velocity meter installation in the return flow outfall building. A summary of return flow volumes to the Root River during the startup and testing phases through September 30, 2023, is included in Table 2-1[1].

Table 2-1. Daily Return Flow Volumes During Startup and Testing

Date	Return Flow Volume (million gallons)
8/1/2023	0.004
8/2/2023	0.004
8/23/2023	0.37
8/24/2023	0.22
8/25/2023	1.22
8/28/2023	0.31
8/29/2023	0.27
8/30/2023	1.60
8/31/2023	1.55
9/1/2023	0.81
9/5/2023	3.50
9/6/2023	2.69

[1] A summary of water supply and return flow volumes in 2023 (including October through December) will be summarized in Sections C and D, respectively, of the Diversion Approval Report for 2023.

Date	Return Flow Volume (million gallons)
9/11/2023	0.25
9/12/2023	3.56
9/13/2023	4.05
9/14/2023	4.73
9/19/2023	0.008
9/25/2023	0.005
9/26/2023	6.14
9/27/2023	3.99
9/29/2023	0.75
Total	36.04

2.1 Root River Flow

Through a cooperative partnership with the City, the USGS also maintains a flow gauge along the Root River approximately 760 feet upstream from the return flow outfall (USGS site 04087234). During the intermittent return flow through September 30, 2023, return flow was between 0 and 55% of the combined river and return flow (Table 2-2). At the time of this report, the river flow data were provisional and most days were noted as estimated flow rates because a beaver dam was observed approximately 650 feet downstream of the gauge (approximately 110 feet upstream of the return flow outfall) creating backwater that may be affecting the gauge accuracy.

Table 2-2. Daily Root River Flows on Days with Return Flow

Average Flow (cfs)				
Day with Return Flow	Root River	Return	Total Flow (Root + Return)	Return % of Total Flow
8/1/2023	15	0.006	15.006	0.0%
8/2/2023	12.2	0.006	12.206	0.1%
8/23/2023	13.2	0.575	13.775	4.2%
8/24/2023	21.2	0.345	21.545	1.6%
8/25/2023	43.3	1.892	45.192	4.2%
8/28/2023	14.6	0.487	15.087	3.2%
8/29/2023	9.88	0.410	10.290	4.0%
8/30/2023	7.87	2.475	10.345	23.9%
8/31/2023	9.58	2.398	11.978	20.0%
9/1/2023	6.63	1.253	7.883	15.9%
9/5/2023	4.38	5.415	9.795	55.3%
9/6/2023	6.36	4.161	10.521	39.6%
9/11/2023	18	0.387	18.387	2.1%
9/12/2023	39.3	5.507	44.807	12.3%
9/13/2023	37.6	6.265	43.865	14.3%

Average Flow (cfs)				
Day with Return Flow	Root River	Return	Total Flow (Root + Return)	Return % of Total Flow
9/14/2023	35.9	7.317	43.217	16.9%
9/19/2023	15.8	0.012	15.812	0.1%
9/25/2023	6.98	0.008	6.988	0.1%
9/26/2023	39.1	9.500	48.600	19.5%
9/27/2023	212	6.176	218.176	2.8%
9/29/2023	252	1.154	253.154	0.5%

Notes:
All data noted by USGS to be provisional.
cfs = cubic foot/feet per second

Annual Root River flow statistics 7Q10, Q80, Q10, and August Q50 at the USGS gage upstream of the return flow outfall (USGS site 04087234) and in Racine (USGS site 04087240) were requested by WDNR for pre-diversion conditions (Table 2-3). These statistics were calculated by USGS (USGS 2024); however, data were summed together for USGS sites 04087220 (Ryan Road) and 04087233 (Root River Canal at 6 Mile Road) because site 04087234 had only been operational since October 2016 and does not have a sufficient dataset. While the summed data appear to be similar to the period since October 2016, USGS noted the following challenges with the dataset because the annual 7Q10 is less at the downstream location than at the upstream location:

- If the flows from the two upstream sites reach site 04087234 at different times, this could affect the statistic calculations because the flows would not be additive.
- The Root River may be a losing reach between these upstream and downstream sites.

Table 2-3. Pre-Diversion Root River Flow Statistics

Flow Statistic	Site 04087234 Discharge (cfs)[a]	Site 04087240 Discharge (cfs)
Annual 7Q10	2.82	1.40
Annual Q80	12.1	18.0
Annual Q10	238	440
August Q50	14.8	23.0

Note:
[a] Estimated by summing flow from USGS sites 04087220 (Ryan Road) and 04087233 (Root River Canal at 6 Mile Road)

2.2 Root River Water Level and Velocity

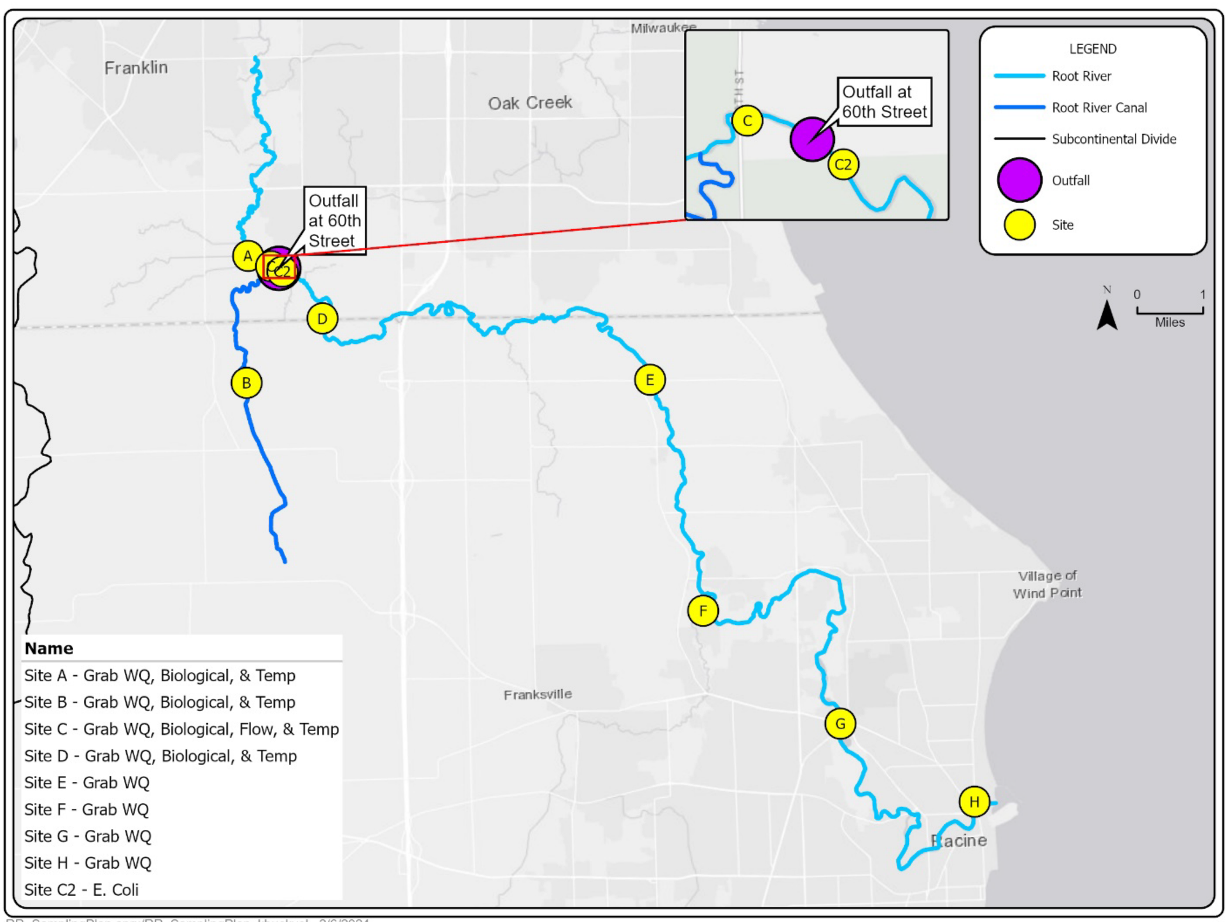
On the day with the greatest percentage of return flow (9/5/2023), the Root River had very low flow (4.38 cfs) compared to an average September monthly flow of approximately 100 cfs (Table 2-2). Based on the USGS stream gauge rating curve, the return flow (5.415 cfs) raised the water surface by 2.28 inches. The velocity change is anticipated to be less than 0.3 foot per second (fps) based on hydraulic modeling completed during the application where an 18 cfs return flow rate resulted in an estimated 0.3 fps increase during 3 cfs low river flow conditions[2]. In future years when return flow consistently outfalls to the Root River, a hydraulic model can be used to assess velocity changes from the range of return flow and river flow rates observed over the year.

3 Monitoring Locations

Monitoring locations were upstream and downstream of the return flow outfall location (Figure 3-1). These include the following:

- Sampling at Sites A, B, C, D, E, F, G, and H was initiated in 2017 as part of the Pre-Return Flow Root River Data Collection Plan.
- Sampling at Site E and Site H was discontinued in 2020.
- Sites A, B, C, and D include water quality and biological monitoring.
- Sites A through H, minus Site C2, include water quality monitoring.
- Site C2 is only for temperature monitoring and was initiated in October 2023 as part of the Post-Return Flow Root River Monitoring Plan.

Figure 3-1. Monitoring Locations



[2] Refer to Appendix K, Table 3, in Volume 4, City of Waukesha Return Flow Plan, of the City of Waukesha Application for Lake Michigan Diversion with Return Flow.

4 Water Temperature

Continuous temperature monitoring at Sites A, B, C, and D has been conducted by USGS since September 2016. Two HOBOTemp temperature data sondes are used at Sites A, B, and D. Temperature at Site C is captured by an automated USGS gauge.

Data from sondes are regularly offloaded and the sondes are maintained and redeployed according to USGS continuous monitoring protocols. Temperature data were collected at hourly intervals at Sites A, B, and D and at 15-minute intervals at Site C.

4.1 Pre-Diversion Temperature

Pre-diversion temperatures at Sites A, B, C, and D are shown on Figures 4-1 and 4-2. A daily average temperature was calculated by averaging the hourly or 15-minute data by calendar day. Ambient river temperatures are seasonal at all sites, where water temperature is coldest in December and January, and warmest in July and August. Average daily temperature across all sites during the pre-diversion period typically varied by less than 1 degree Fahrenheit.

Sites A and B were plotted together to compare temperature variations from the canal (Site B) and the mainstem (Site A). During most times of year (January to March and June to December), Site B is between 0 and 2 degrees warmer than Site A, on average. Two existing wastewater discharges on the Canal may influence the ambient temperature at Site B, causing the difference in temperature compared to Site A. Both Sites A and B are upstream of the return flow location.

Sites C and D were compared to establish a baseline condition of locations upstream (Site C) and downstream (Site D) of the future return flow discharge location. There were fewer variations in temperature between Sites C and D during the pre-diversion period when return flow was not present. There was not a consistent time of year where either site was warmer when comparing daily and monthly averages.

2022 was notably different than other pre-diversion years where temperature was warmer than previous years at Site C, and where it was warmer on average than Site D. Site A also experienced warmer temperatures in 2022, which may have influenced the temperature at Site C. There are no known causes or events in 2022 that directly influenced the in-stream ambient temperatures.

Figure 4-1. Daily Average Temperature at Sites A and B

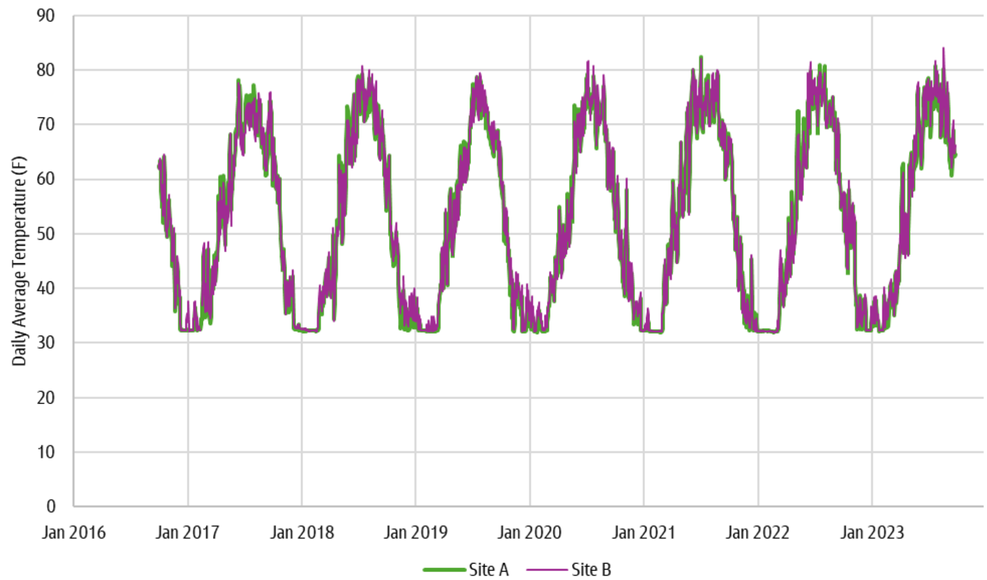


Figure 4-2. Daily Average Temperature at Sites C and D

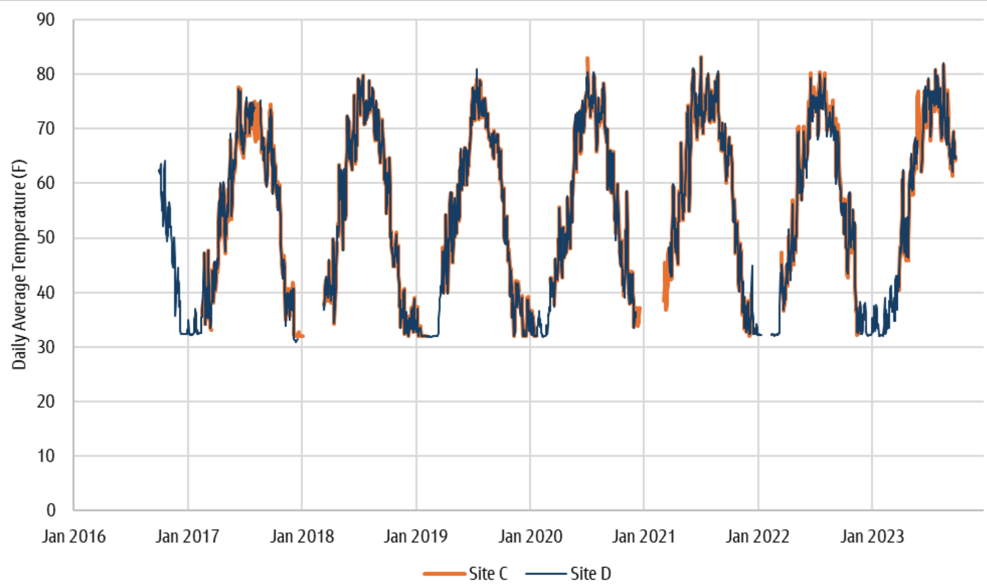


Table 4-1 summarizes the temperature thresholds for the Root River. The ambient temperatures are site specific for Root River at Site C, while the sublethal and acute temperatures are default temperature thresholds for warm small rivers from Wisconsin Administrative Code NR102 (WDNR 2024).

Table 4-1. Monthly Temperature Thresholds

Month	Temperature Thresholds (°F)		
	Ambient	Sublethal	Acute
January	33	49	76
February	34	50	76
March	39	52	77
April	47	55	79
May	59	65	82
June	69	76	84
July	74	81	85
August	72	81	84
September	66	73	82
October	55	61	80
November	42	49	77
December	34	49	76

Note:
°F = degree(s) Fahrenheit

Daily average temperature exceedances of the ambient, sublethal, and acute temperature thresholds (Table 4-1) were assessed for Site C and Site D during the pre-diversion period (Table 4-2). The daily average temperature was compared to the monthly temperature threshold and exceedances were summed. For example, if the daily average temperature at Site C exceeded the January ambient temperature threshold on January 3 and January 15, two exceedances were reported.

Table 4-2. Summary of Temperature Threshold Exceedances at Sites C and Site D using Daily Average Temperatures

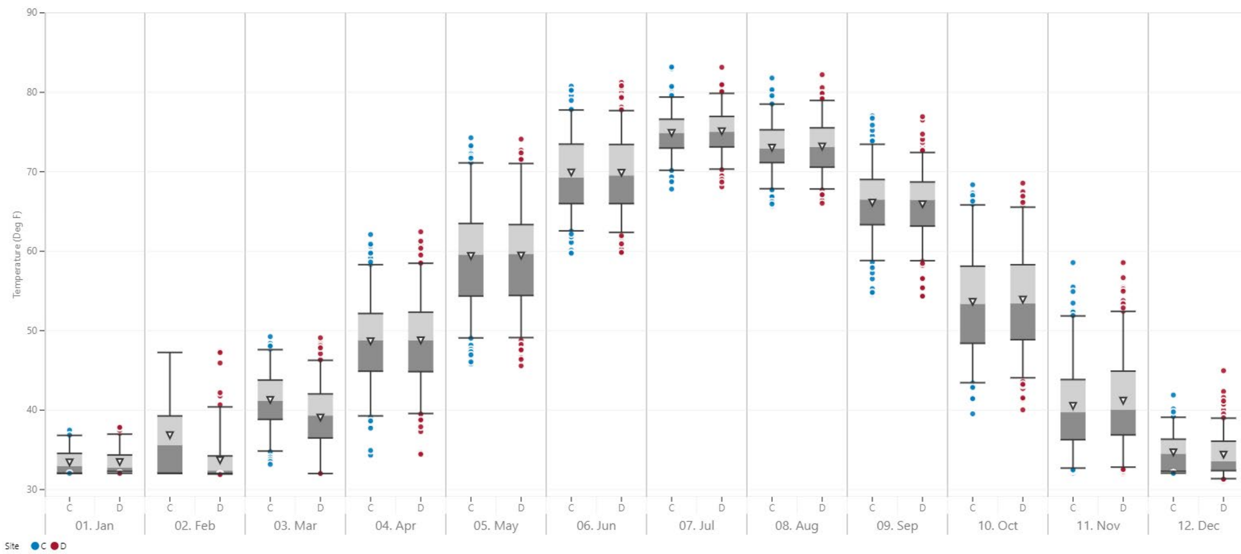
	Site C			Site D		
Month	Ambient	Sublethal	Acute	Ambient	Sublethal	Acute
January[a]	28	-	-	60	-	-
February[a]	11	-	-	32	-	-
March[a]	78	-	-	97	-	-
April	129	28	-	133	31	-
May	114	41	-	115	43	-
June	109	28	-	104	29	-
July	131	2	-	131	1	-
August	138	1	-	125	1	-
September	111	12	-	113	7	-

Month	Site C			Site D		
	Ambient	Sublethal	Acute	Ambient	Sublethal	Acute
October	78	26	-	93	37	-
November	56	15	-	74	26	-
December[a]	68	-	-	85	-	-

Notes:
"-" indicates that no temperature threshold exceedances were recorded.
[a] Ice conditions during winter months limit USGS temperature data collection. December and March months have daily data for most years; however, January and February had significant data gaps with 58 and 18 total days with data, respectively, at Site C between 2017 and 2023.

A box and whisker plot of the 15-minute and hourly temperatures for Site C and Site D is shown on Figure 4-3. The box represents the 25th through the 75th percentile of data, where 50% of the datapoints are within the box. The center line in the box represents the median and the triangle represents the mean. The lower and upper whiskers represent the 5th and 95th percentile, where 90% of the datapoints are between the whiskers. Outliers from the dataset are shown as points. Data limitations noted on Table 4-2 apply equally to Figure 4-3.

Figure 4-3. Temperature Data Box and Whisker Plots at Site C and Site D



4.2 Post-Diversion Temperature

This report includes pre-diversion conditions through September 30, 2023. Post-diversion Root River temperature will be summarized in future annual reports to address the following topics:

- Changes in river temperature upstream and downstream of return flow
- Seasonal differences
- Spatial extent of temperature changes caused by return flow

5 Water Quality

During the pre-diversion period, water quality was measured using onsite field water quality meters and state-accredited laboratories as described in the Pre-Return Flow Root River Data Collection Plan (CH2M 2017). Water quality was assessed at eight sampling locations, Sites A through H, although monitoring was discontinued at two sites (Sites E and H) during the pre-diversion period.

5.1 Data Quality

Water quality data collected as part of the pre-diversion monitoring activities were quality controlled at the end of the pre-diversion monitoring period. Field data were reviewed to identify and assess outliers resulting from potential field equipment malfunctions, inaccurate meter calibration, sampling method errors, or other conditions noted by the field teams. Outlier data points that were judged to be the result of field equipment malfunctions, inaccurate meter calibration, and sampling method errors were removed from the dataset. Laboratory data were similarly reviewed, but no data points were removed. Remaining data points that were outside of the parameter expected ranges, as defined in the Post-Return Flow Root River Monitoring and Quality Assurance Project Plan (QAPP; Jacobs 2023), are discussed in the following sections.

5.2 Pre-Diversion Water Quality

A summary of water quality during the pre-diversion period for Sites A through H is shown in Table 5-1.

As part of the QAPP, expected data ranges were established to support assessing data quality. The last two columns in Table 5-1 show the number and percent of data points that fell outside of the parameter expected range during the pre-diversion period.

Parameters that include data points outside of the QAPP expected range include dissolved oxygen, turbidity, orthophosphate, TSS, and chlorophyll. For all parameters except orthophosphate, the percent of data points that fell outside of the QAPP expected range was less than 2%.

Data points outside of the dissolved oxygen and turbidity expected ranges are greater than the 15 milligrams per liter (mg/L) and 120 nephelometric turbidity units (NTU) expected maximums, respectively. For both dissolved oxygen and turbidity, these occurrences may be the result of field water quality meter malfunctions or inaccurate calibrations. In most cases, where field teams did not note issues with the equipment or field procedures, the dissolved oxygen and turbidity data have remained in the dataset. In a few instances, data were removed if levels were clearly inaccurate based on professional judgment.

Some occurrences of high turbidity levels coincided with precipitation events where temporary increases in turbidity may be reasonable. Similarly, these data have remained in the dataset. Dissolved oxygen results are further discussed in the following sections.

Data points outside of the orthophosphate expected range are less than the 0.01 mg/L orthophosphate minimum. The orthophosphate expected range was set based on the anticipated laboratory limit of detection and, therefore, orthophosphate results less than 0.01 mg/L do not impact pre-diversion water quality conclusions.

Data points outside of the TSS expected range are greater than the 175 mg/L expected maximum. Data points outside of the chlorophyll expected range are greater than the 360 mg/L expected maximum.

For TSS and chlorophyll, these occurrences were infrequent, passed quality assurance and control procedures by the Wisconsin State Laboratory of Hygiene, and were, therefore, kept in the dataset.

A summary of water quality during the pre-diversion period for Site C and Site D, upstream and downstream of the outfall, respectively, is shown in Table 5-2. Water quality and corresponding statistics for Sites C and D are similar.

Table 5-1. Pre-Diversion Water Quality Summary, Sites A through H

Parameter	Unit	All Sites (A-H)[a]					
		5th Percentile	Average ± Standard Deviation	95th Percentile	QAPP Expected Range[b]	Data Points Outside of Expected Range	Percent of Data Points Outside of Expected Range (%)
pH	S.U.	7.26	7.85 ± 0.36	8.38	6 to 10	0	0
Dissolved Oxygen	mg/L	5.41	9.54 ± 2.95	14.41	0.01 to 15	90	2
Temperature	deg Celsius	-0.10	13.87 ± 8.55	24.30	-5 to 35	0	0
Turbidity	NTU	2.28	19.4 ± 25.77	60.37	0.1 to 120	36	1
Specific Conductance	mS/cm	0.63	1.1 ± 0.36	1.68	0.1 to 10	0	0
Phosphorus	mg/L	0.04	0.13 ± 0.09	0.30	0.01 to 5	0	0
Orthophosphate	mg/L	0.01	0.04 ± 0.04	0.12	0.01 to 3	124	14
Total Nitrogen	mg/L	0.81	2.54 ± 1.69	5.70	0.01 to 15	0	0
Nitrate-Nitrite	mg/L	0.13	1.64 ± 1.6	4.65	0.01 to 15	0	0
Ammonia	mg/L	0.02	0.07 ± 0.08	0.19	0.01 to 3	0	0
Total Suspended Solids	mg/L	5.40	31.04 ± 42.65	90.05	1 to 175	11	1
Chlorophyll	µg/L	1.65	14.5 ± 34.51	53.15	0.01 to 360	3	0

Notes:

[a] Data collection at Site E and Site H was discontinued starting in 2020.

[b] Post-Return Flow Root River Monitoring Plan and Quality Assurance Project Plan. Jacobs, 2023.

µg/L = microgram(s) per liter

deg Celsius = degrees Celsius

mg/L = milligram(s) per liter

mS/cm = microsiemens per centimeter

NTU = nephelometric turbidity unit(s)

S.U. = standard unit(s)

Table 5-2. Pre-Diversion Water Quality Summary, Site C and Site D

Parameter	Unit	Site C					Site D				
		5th Perc	Average +/- Standard Deviation	95th Perc	Data Points Outside of Expected Range	Percent of Data Points Outside of Expected Range (%)	5th Perc	Average +/- Standard Deviation	95th Perc	Data Points Outside of Expected Range	Percent of Data Points Outside of Expected Range (%)
pH	S.U.	7.27	7.81 ± 0.28	8.24	0	0	7.33	7.85 ± 0.32	8.34	0	0
Dissolved Oxygen	mg/L	4.78	8.92 ± 3.03	14.10	8	1	5.38	9.1 ± 2.98	14.55	13	2
Temperature	deg Celsius	-0.10	13.68 ± 8.4	23.70	0	0	-0.20	13.78 ± 8.34	23.60	0	0
Turbidity	NTU	3.68	22.34 ± 27.5	70.35	5	1	4.40	21.72 ± 25.19	69.89	9	2
Specific Conductance	mS/cm	0.65	1.11 ± 0.33	1.70	0	0	0.68	1.08 ± 0.29	1.43	0	0
Phosphorus	mg/L	0.05	0.13 ± 0.08	0.31	0	0	0.05	0.13 ± 0.08	0.32	0	0
Orthophosphate	mg/L	0.01	0.04 ± 0.04	0.12	16	12	0.01	0.04 ± 0.04	0.12	16	12
Total Nitrogen	mg/L	0.90	2.41 ± 1.3	4.75	0	0	0.88	2.39 ± 1.35	4.71	0	0
Nitrate-Nitrite	mg/L	0.17	1.55 ± 1.22	3.76	0	0	0.15	1.51 ± 1.25	3.68	0	0
Ammonia	mg/L	0.02	0.07 ± 0.08	0.18	0	0	0.02	0.07 ± 0.08	0.15	0	0
Total Suspended Solids	mg/L	6.32	29.95 ± 35.1	78.80	1	1	6.56	30.59 ± 32.54	88.32	1	1
Chlorophyll	µg/l	1.64	8.92 ± 11.87	22.44	0	0	1.62	12.51 ± 21.37	45.06	0	0

Note:
Perc = percentile

5.2.1 Phosphorus

Average phosphorus levels for growing and non-growing seasons at each site during the pre-diversion period are shown in Table 5-3. Average phosphorus level values less than the water quality criterion of 0.075 mg/L are shaded in green and values greater than the water quality criterion are shaded in yellow.

For most sampling sites and years, phosphorus levels were higher during the growing season compared to the non-growing season. Phosphorus levels at Site B were higher compared to other sites, and phosphorus levels at Site A were lower compared to other sites. These results are consistent with a well-mixed flow downstream of the Root River mainstem and Root River Canal confluence. The higher phosphorus concentrations at Site B may be because the municipal wastewater discharges upstream. In addition, biological activity in the river also may influence phosphorus levels at all sampling sites.

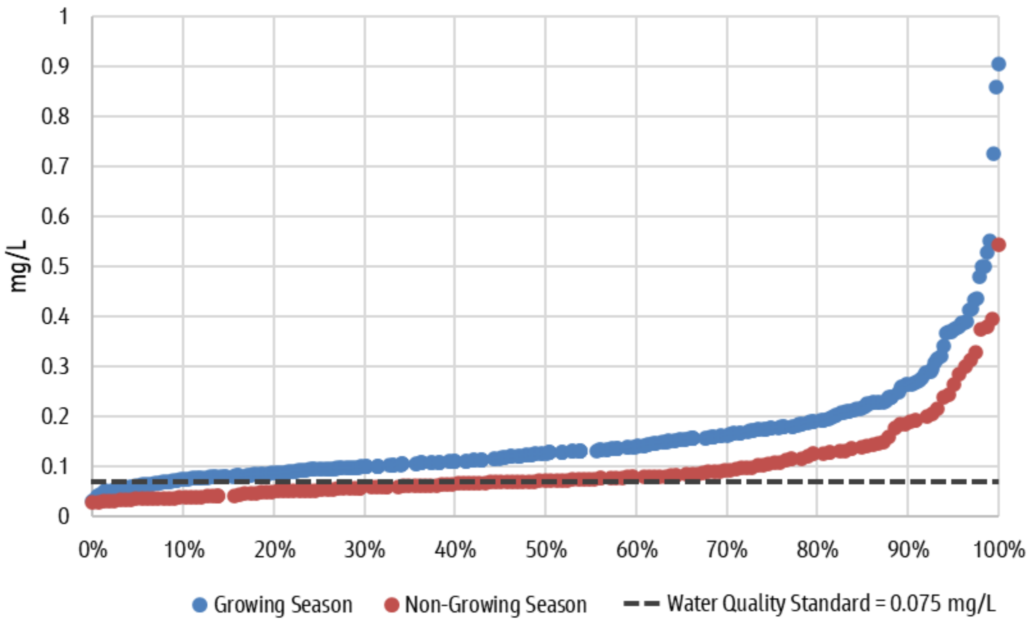
Table 5-3. Average Phosphorus Levels During the Pre-Diversion Period

	All Sites	A	B	C	D	E[a]	F	G	H[a]
Growing Season									
2017	0.143	0.088	0.183	0.132	0.167	0.129	0.128	0.166	0.146
2018	0.161	0.102	0.241	0.149	0.162	0.153	0.153	0.176	0.159
2019	0.175	0.108	0.288	0.170	0.151	0.172	0.162	0.167	0.173
2020	0.173	0.115	0.277	0.179	0.183	-	0.145	0.140	-
2021	0.170	0.134	0.213	0.140	0.143	-	0.166	0.220	-
2022	0.114	0.082	0.150	0.098	0.101	-	0.125	0.131	-
2023	0.134	0.092	0.213	0.117	0.106	-	0.154	0.126	-
Non-Growing Season									
2017	0.097	0.063	0.165	0.095	0.101	0.088	0.079	0.113	0.082
2018	0.082	0.072	0.104	0.067	0.085	0.082	0.061	0.064	0.068
2019	0.108	0.065	0.141	0.115	0.112	0.115	0.133	0.098	0.073
2020	0.068	0.050	0.095	0.063	0.063	-	0.062	0.076	-
2021	0.090	0.069	0.086	0.121	0.082	-	0.062	0.076	-
2022	0.149	0.091	0.238	0.145	0.131	-	0.129	0.079	-
2023	0.064	0.038	0.095	0.058	0.065	-	0.070	0.073	-

Notes:
Average phosphorus level values less than the water quality criterion of 0.075 mg/L are shaded in green and values greater than the water quality criterion are shaded in yellow.
[a] Data collection at Site E and Site H was discontinued starting in 2020.

Phosphorus levels during the growing season and non-growing season at Sites A through D for all years during the pre-diversion period are shown in Figures 5-1 through 5-4. Key takeaways are summarized below each figure.

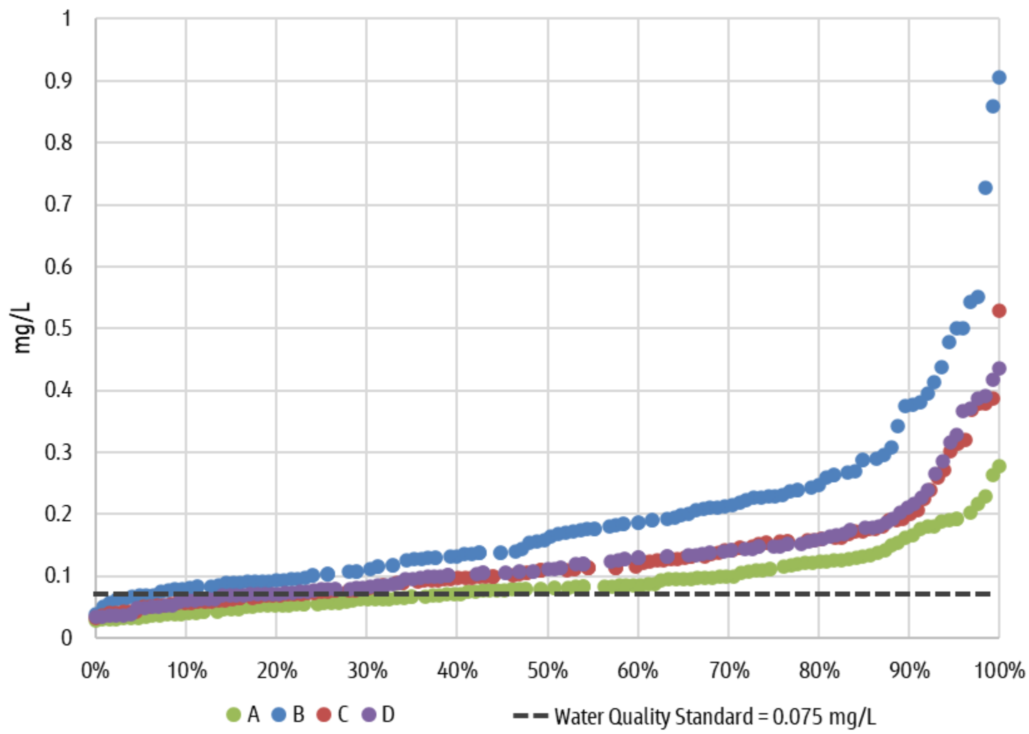
Figure 5-1. Phosphorus Levels Cumulative Percentile, Sites A through D during Growing and Non-Growing Seasons



Key Takeaways:

- Phosphorus levels are higher during the growing season, which is consistent with seasonal fertilizer application and subsequent runoff and impacts to phosphorus levels in wastewater discharges.
- Biological activity in the river during growing and non-growing seasons also may influence the observed phosphorus cycling.
- Approximately 90% of all samples measured during the growing season were greater than the water quality standard of 0.075 mg/L compared to 45% of all samples measured during the non-growing season.

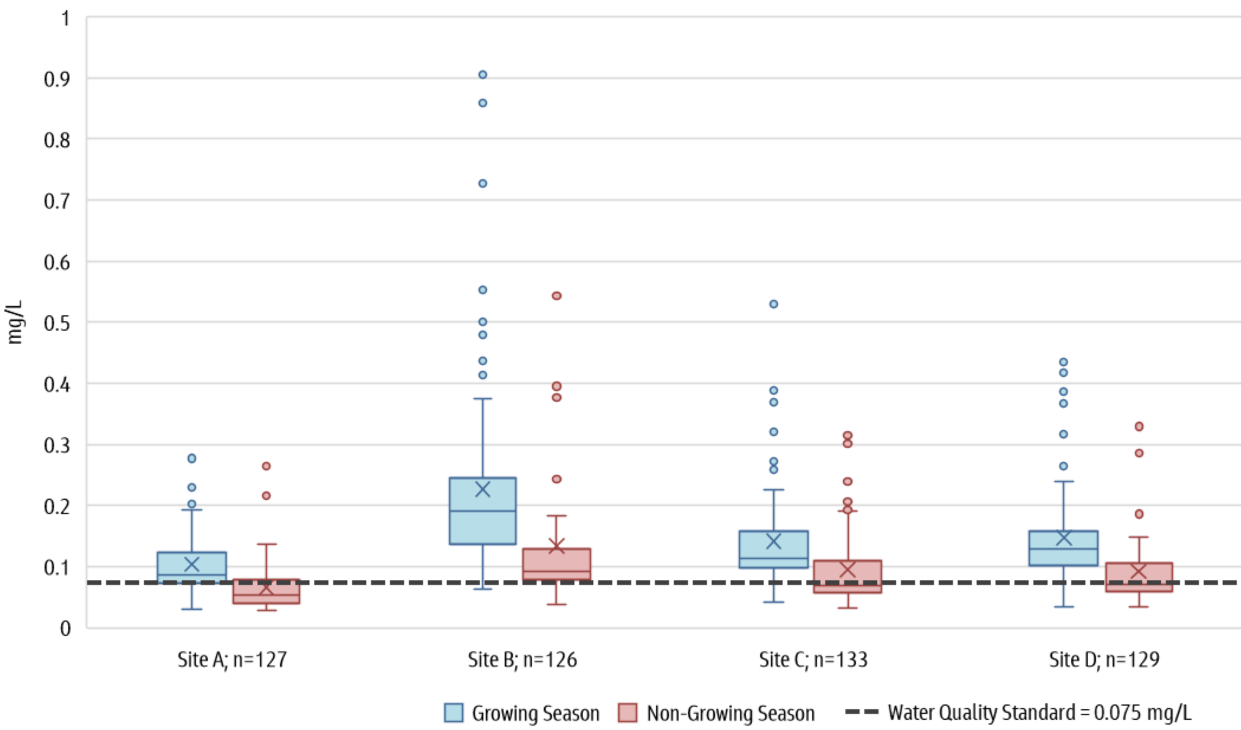
Figure 5-2. Phosphorus Levels Cumulative Percentile, Sites A through D



Key Takeaways:

- Phosphorus levels are higher at Site B, which may be explained by the presence of two active wastewater discharges at the Root River Canal upstream of Site B.
- Biological activity in the river also may influence the observed phosphorus results.

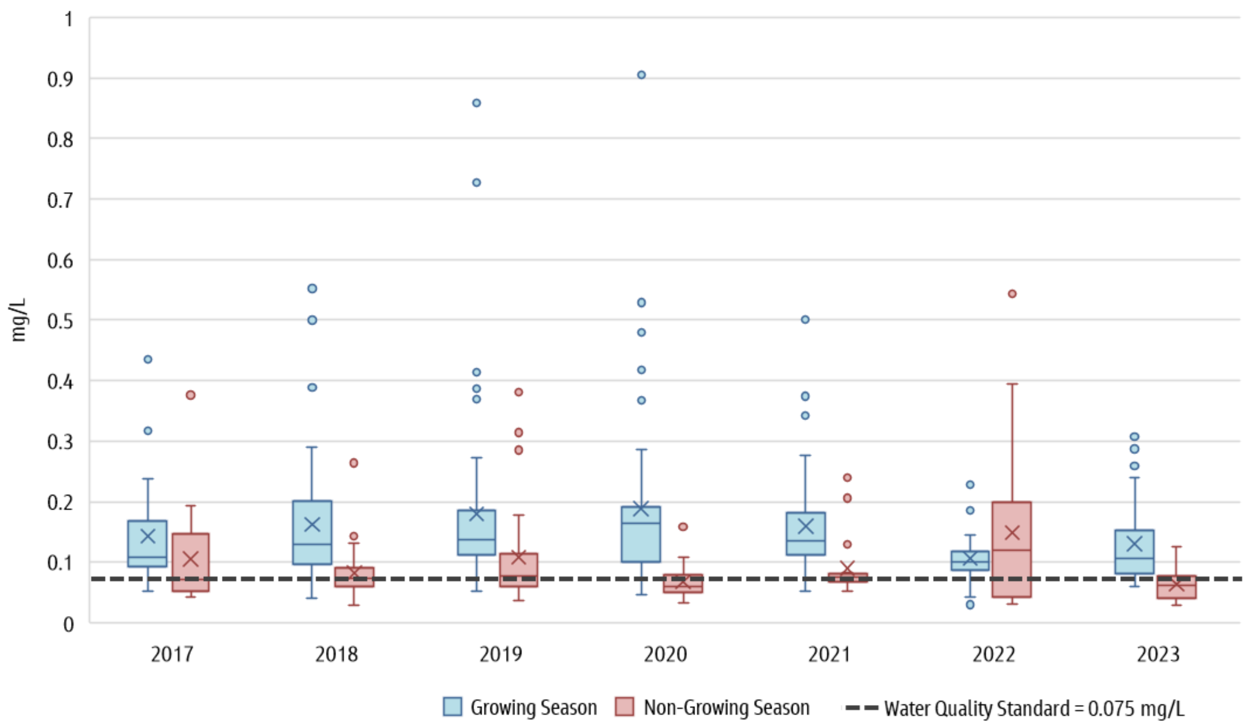
Figure 5-3. Phosphorus Levels Box and Whisker Plot, Sites A through D



Key Takeaways:

- Phosphorus levels are higher and more variable at Site B, which may be because of wastewater discharges upstream of the sampling site.
- Downstream of the confluence of the Root River mainstem and Canal at Site C and Site D, phosphorus levels demonstrate a mixed flow from phosphorus levels at Site A and Site B.
- Site A data show the lowest variability in phosphorus levels among the four sites.
- Average phosphorus levels during the growing season were greater than the water quality standard for all sites. Average phosphorus levels during the non-growing season were greater than the water quality standard for all sites except Site A.
- Variations in biological activity near the sampling sites also may influence the observed phosphorus results.

Figure 5-4. Phosphorus Levels Box and Whisker Plot – Sites A through D by Season and Year



Key Takeaways:

- Annual trends during growing and non-growing seasons are consistent with elevated and more variable phosphorus levels during the growing season.
- Sampling in 2022 showed a different trend with greater average phosphorus and greater variability in phosphorus levels during the non-growing season.
- Average phosphorus levels during the growing season were greater than the water quality standard for all years. Average phosphorus levels during the non-growing season were greater than the water quality standard for all years except 2020 and 2023.
- Variations in biological activity in the river also may influence the observed phosphorus results.

5.2.2 Field pH

Average pH levels for growing and non-growing seasons at each site during the pre-diversion period are shown in Table 5-4. A relative color scale from yellow to blue for increasing average pH levels is used to visually compare the season, year, and sampling site.

The results demonstrate that average pH levels at the sampling sites are typically between 7.4 and 8.2, and slightly higher pH levels are observed at downstream sites compared to upstream.

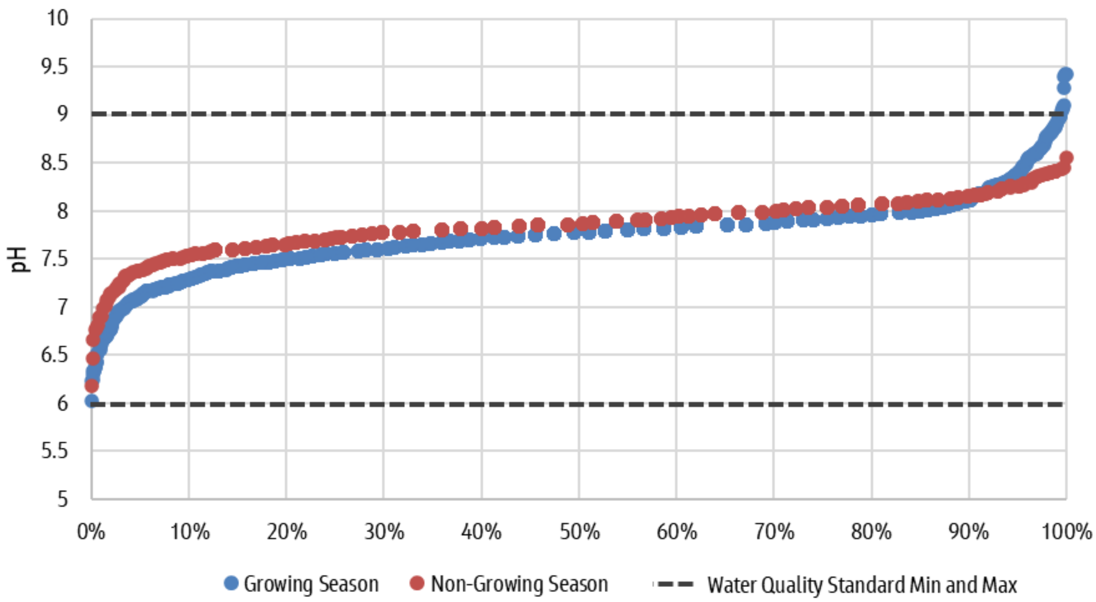
Table 5-4. Average pH Levels for Growing and Non-growing Seasons

	All Sites	A	B	C	D	E	F	G	H
Growing Season									
2017	7.85	7.72	7.71	7.81	7.81	7.80	8.02	8.05	7.88
2018	7.72	7.57	7.55	7.66	7.69	7.69	7.90	7.87	7.82
2019	7.75	7.54	7.62	7.70	7.71	7.72	7.90	7.94	7.86
2020	7.82	7.58	7.65	7.81	7.83	-	7.96	8.12	-
2021	7.75	7.36	7.80	7.72	7.76	-	7.87	8.01	-
2022	7.91	7.77	7.89	7.81	7.87	-	8.08	8.05	-
2023	8.02	8.03	8.08	7.85	7.96	-	8.15	8.03	-
Non-Growing Season									
2017	7.86	7.73	7.67	7.76	7.86	7.82	8.03	7.97	8.03
2018	7.89	7.68	7.80	7.84	7.88	7.87	8.00	7.97	8.07
2019	7.93	7.77	7.79	7.96	7.98	7.98	7.96	7.96	8.20
2020[a]	7.86	7.44	7.75	7.89	7.96	-	8.04	8.06	-
2021	8.07	7.70	8.02	8.14	8.22	-	8.17	8.22	-
2022	7.95	7.83	7.85	7.92	7.97	-	8.09	8.03	-
2023	7.94	7.95	7.73	7.93	7.93	-	8.03	8.08	-

Note:
[a] Data collection at Site E and Site H was discontinued starting in 2020.

Field pH measurements during the growing season and non-growing season at Sites A through D for all years during the pre-diversion period are shown on Figures 5-5 through 5-8. Key takeaways are summarized below each figure.

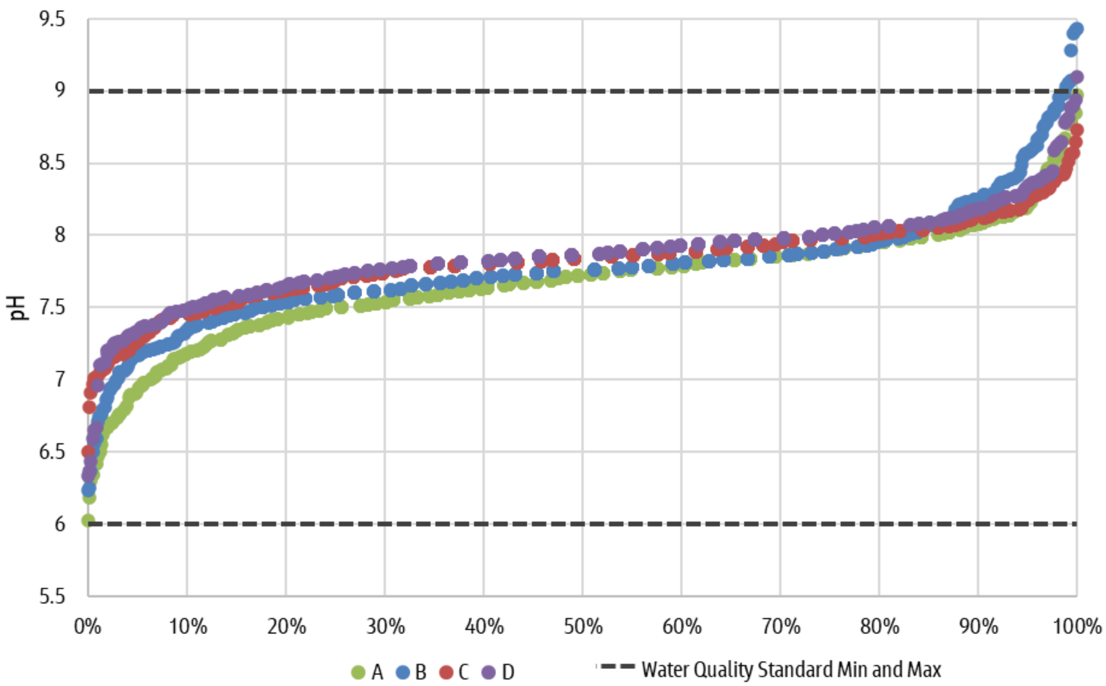
Figure 5-5. Field pH – Cumulative Percentile by Season



Key Takeaways:

- For most data points, pH is slightly higher during the non-growing season compared to the growing season. This may be caused by fertilizer applications increasing soil acidity and subsequent soil runoff during the growing season.
- Nearly all pH measurements fell within the water quality standard minimum of 6 and maximum of 9.
- Biological activity in the river during growing and non-growing seasons also may influence the observed pH levels.

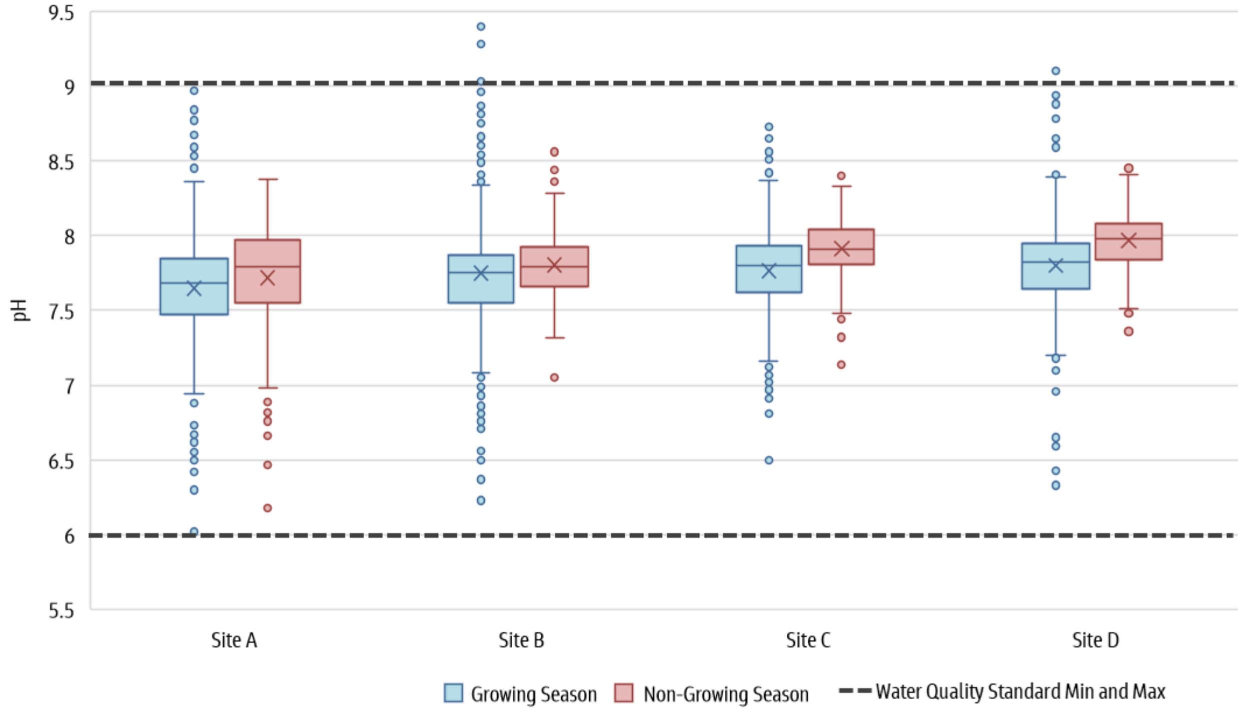
Figure 5-6. Field pH – Cumulative Percentile for Sites A through D



Key Takeaways:

- Unlike other water quality parameters, pH levels do not appear to be the result of a mixed river flow at Sites A and B. For most of the dataset, pH Levels at Sites A and B are slightly lower compared to Sites C and D.
- Nearly all pH measurements fell within the water quality standard minimum of 6 and maximum of 9.
- Variations in biological activity in the river at different sampling sites also may influence the observed pH levels.

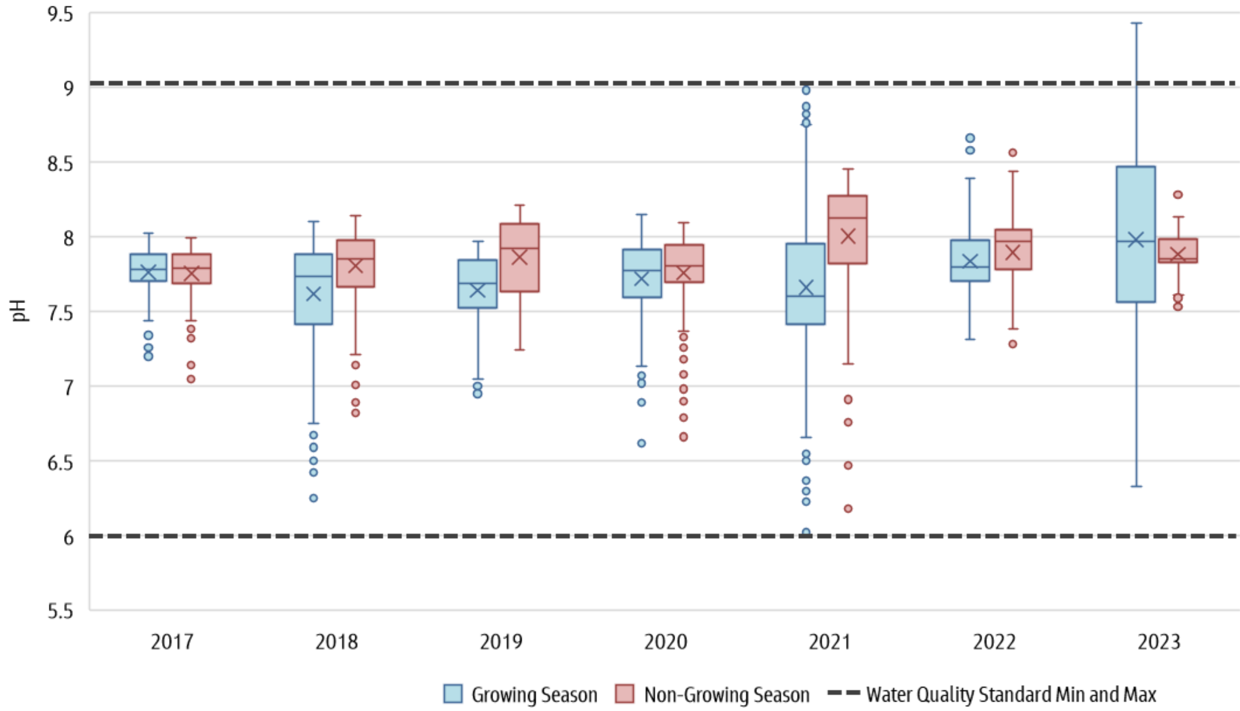
Figure 5-7. Field pH Box and Whisker Plot by Site and Growing Season



Key Takeaways:

- For all sites, the average pH is slightly higher during the non-growing season compared to the growing season. This may be caused by fertilizer applications increasing soil acidity and subsequent soil runoff during the growing season.
- For all sites, greater variability in pH levels is observed during the growing season.
- Nearly all pH measurements fell within the water quality standard minimum of 6 and maximum of 9.
- Biological activity in the river during growing and non-growing seasons and at different sites also may influence the observed pH levels.

Figure 5-8. Field pH Box and Whisker Plot for Sites A through D by Year and Growing Season



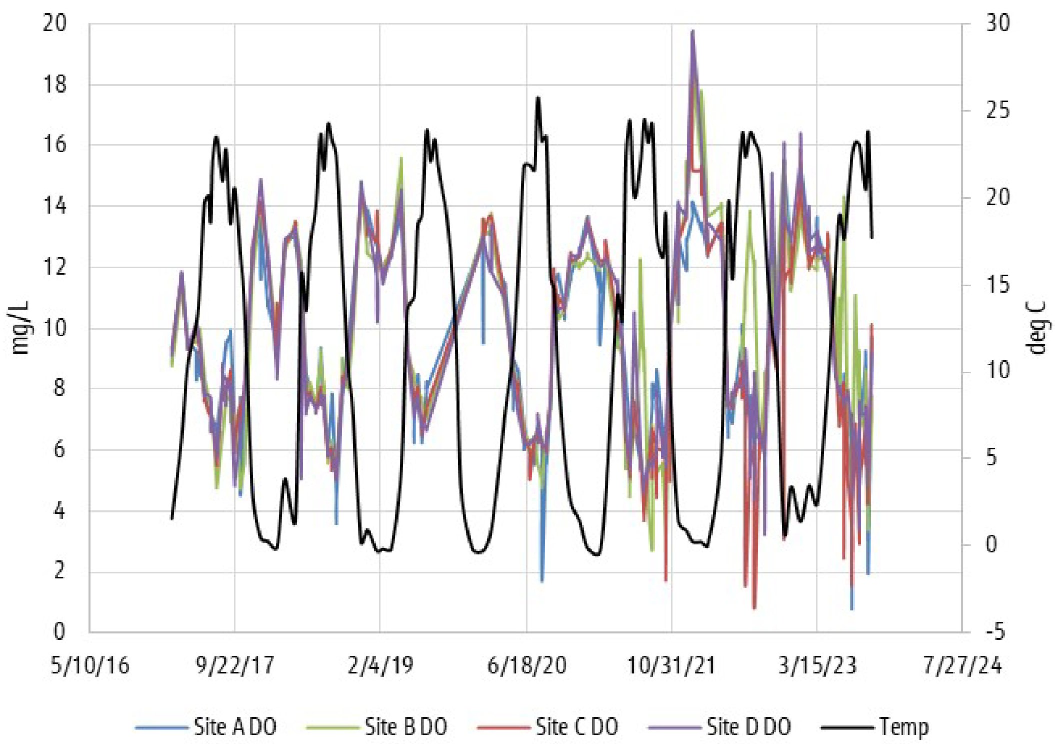
Key Takeaways:

- For most years, the average pH is slightly higher during the non-growing season compared to the growing season. This may be caused by fertilizer applications increasing soil acidity and subsequent soil runoff during the growing season.
- Biological activity in the river during growing and non-growing seasons and at different sites also may influence the observed pH levels.
- Nearly all pH measurements fell within the water quality standard minimum of 6 and maximum of 9.

5.2.3 Field Dissolved Oxygen

Field dissolved oxygen measurements during the growing season and non-growing season at Sites A through D for all years during the pre-diversion period are shown on Figures 5-9 and 5-10. Key takeaways are summarized below each figure.

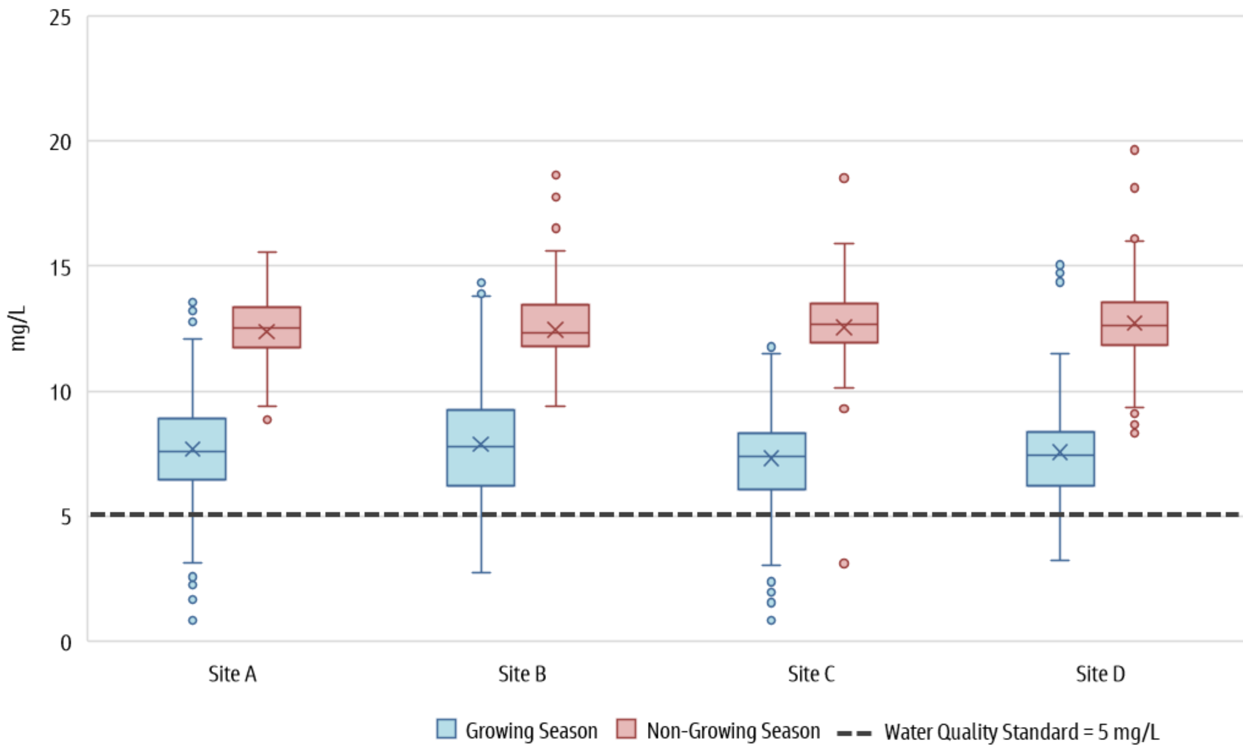
Figure 5-9. Field Dissolved Oxygen for Sites A through D



Key Takeaways:

- Dissolved oxygen and temperature are inversely related, with high dissolved oxygen levels observed at low water temperatures.
- Some dissolved oxygen measurements are greater than the theoretical maximum dissolved oxygen. According to theoretical oxygen solubility in distilled water, dissolved oxygen can reach a maximum level of 14.6 mg/L at 0 degrees Celsius. Approximately 4% (n = 146) of all dissolved oxygen measurements during the pre-diversion period were greater than 14.6 mg/L. This suggests that dissolved oxygen measurements greater than 14.6 mg/L may be exaggerated or inaccurate or may be influenced by additional factors. Supersaturation of oxygen in the river water resulting in dissolved oxygen measurements greater than 14.6 mg/L also can be caused by photosynthesis by aquatic plants and algae. Because these results cannot be directly linked to an equipment malfunction, sampling method error, or photosynthetic activity, they remain in the dataset.

Figure 5-10. Field Dissolved Oxygen – Box and Whisker Plot by Site and Season



Key Takeaways:

- Dissolved oxygen levels and variability are similar across the sampling sites between growing and non-growing season periods.
- Most dissolved oxygen measurements were greater than the minimum water quality standard of 5 mg/L for all sampling sites.

5.2.4 Total Suspended Solids

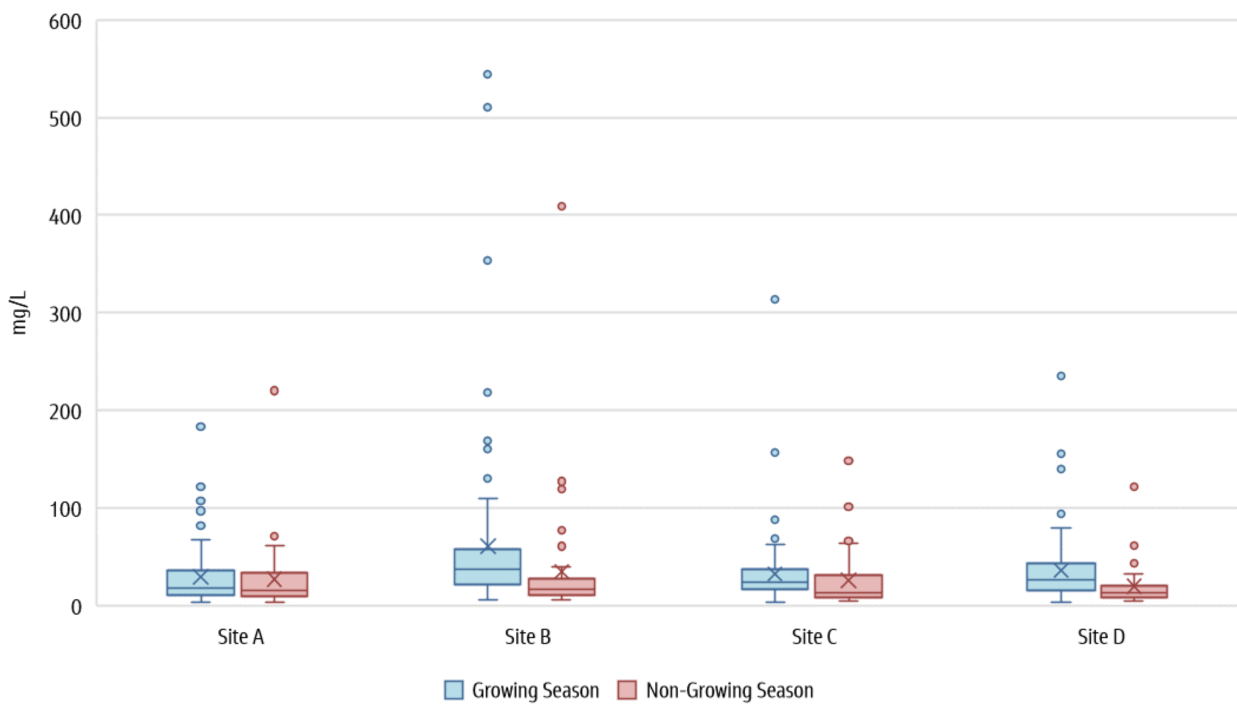
Average total suspended solids (TSS) levels for growing and non-growing seasons at each sampling site during the pre-diversion period are shown in Table 5-5. For all sampling sites, TSS was higher during the growing season compared to the non-growing season.

Table 5-5. Average TSS Levels by Site and Season

Season	Site A	Site B	Site C	Site D
Growing Season	29.1	60.8	32.3	35.8
Non-Growing Season	27.0	34.6	25.3	19.5

TSS measurements during the growing and non-growing season at Sites A through D for all years during the pre-diversion period are shown on Figure 5-11. Key takeaways are summarized below the figure.

Figure 5-11. Total Suspended Solids Box and Whisker Plot by Site and Season



Key Takeaways:

- Although there is no numeric water quality standard for TSS, total maximum daily loads (TMDLs) in Wisconsin have used in-stream targets ranging between 12 and 26 mg/L[3]. During the growing season, 54% of all TSS measurements were less than 26 mg/L. During the non-growing season, 80% of all TSS measurements were less than 26 mg/L.
- Data points outside of the expected range of 1 to 175 mg/L accounted for 1% of all measurements and all were greater than 175 mg/L. Outliers are believed to be the result of acute environmental events such as water disturbances from precipitation, bank erosion, or disturbance of the riverbed by the sampling team.

[3] The Lower Fox River TMDL used a TSS target of 18 mg/L, the Rock River TMDL used 26 mg/L, and the Milwaukee River, Upper Fox and Wolf Rivers, and the ongoing Illinois Fox River TMDLs used 12 mg/L.

5.2.5 Watershed Impacts

Watershed impacts from environmental events as well as human activity during the pre-diversion period were reviewed to assess potential observational impacts in recorded water quality data. The following activities were completed to summarize watershed impacts during the pre-return flow data collection period:

- Contacted Milwaukee RiverKeeper and Root-Pike Watershed Initiative Network for records of environmental releases and similar impacts.
- Performed internet searches for local news stories.
- Queried the Milwaukee Journal Sentinel online articles.
- Obtained records from the WDNR Spills Coordinator.
- Had verbal conversations with local farmers.

Upstream of the return flow outfall on the Root River Canal, upstream of Site B, there are two active wastewater discharges governed by Wisconsin Pollutant Discharge Elimination System permits. Both facilities operate under a multi-discharger variance for phosphorus and are therefore permitted to have phosphorus discharges above the water quality criterion. Water quality data collected during the pre-diversion period demonstrate higher phosphorus levels at Site B consistent with the presence of these discharges.

To assess acute impacts to the Root River during the pre-diversion monitoring period, spill activities were reviewed using the WDNR Environmental Cleanup and Brownfields Redevelopment database. During the pre-diversion period, a total of seven spills were recorded along the Root River, with three spills located downstream of the sampling sites. Spill activity in the Root River area from 2016 to 2023 with potential impacts to sampling sites are shown in Table 5-6.

Table 5-6. Spill Incidents along Root River Sampling Sites in the Pre-Diversion Period

Start and End Date	Spill Substance	Amount Released	Location	Potential Sampling Site(s) Impacted	Description
8/16/2018 to 8/27/2018	Gasoline	1 Qt	761 Marquette St	Site H	Gasoline release from boat located in the marina
10/26/2018 to 11/5/2018	Unknown Oil, Fuel, or Grease Product	Unknown	761 Marquette St	Site H	Hydraulic line break caused release and subsequent sheen on river surface
5/5/2023 to 8/11/2023	Diesel Fuel	Unknown	State Highway 38 and 5 Mile Rd	Site F and Site G	Oil observed on river surface coming from creeks feeding the river
9/1/2023 to 1/17/2024	Unknown Petroleum	Unknown	State Highway 38 and Johnson Ave	Site G	Abandoned vehicle leaking large amounts of oil or hydraulic fluid

Turbidity and pH data were reviewed to assess the impacts of gasoline, fuel, and petroleum spills. For all spill date ranges, no substantial deviations in data results were observed. Elevated turbidity levels of approximately 150 NTU were observed in two of five samples taken at the river crossing at Site H on October 29, 2018. Minor variations in pH (values between 6.7 and 9.1) were observed at Site F and

Site G from May through June in 2023. However, they remained within QAPP expected data ranges. In both cases, these data variations are not conclusively linked to the spill activities during the pre-diversion period.

5.3 Post-Diversion Water Quality

This report includes pre-diversion conditions. Post-diversion Root River water quality will be summarized in future annual reports to address the following topics:

- Changes in river water quality upstream and downstream of return flow
- Seasonal differences
- Impact of upstream watershed impacts that may be influencing observed changes in river water quality

6 Water-Dependent Resources

Fishery, benthic macroinvertebrate, and quantitative habitat evaluation surveys were completed at Sites A through D starting in 2017. Two events were completed for fish and macroinvertebrates, one during the traditional season near September, and again in November. Table 6-1 summarizes the pre-return flow sampling dates between 2017 and 2023.

Table 6-1. Pre-Return Flow Macroinvertebrate and Habitat Survey Events

Year	Benthic Macroinvertebrate Sampling		Quantitative Habitat Evaluation			
	September	November	Site A	Site B	Site C	Site D
2017	Sept. 11	Nov. 2	Sept. 21	Sept. 19	Sept. 24	Sept. 19
2018	Sept. 13	Nov. 17	Sept. 27	Sept. 20	Sept. 14	Sept. 14
2019	Sept. 5	Nov. 13	Sept. 6	Sept. 20	Sept. 26	Nov. 14
2020	Sept. 3	Nov. 4	Sept. 18	Sept. 11	Sept. 24	Sept. 17
2021	Sept. 3	Nov. 3	Aug. 5	July 27	July 29	Aug. 6
2022	Sept. 2	Nov. 2	July 13	July 8	July 14	July 18
2023		n/a				

n/a = not applicable because survey event was not within pre-return flow conditions.

Table 6-2 summarizes the sampling dates for the pre-return flow fish surveys conducted between 2017 and 2023. All sites were sampled as part of the same survey, except in 2017, when a second event for Sites C and D was required to ensure the sampling was conducted over the defined study reach.

Table 6-2. Pre-Return Flow Fish Survey Events

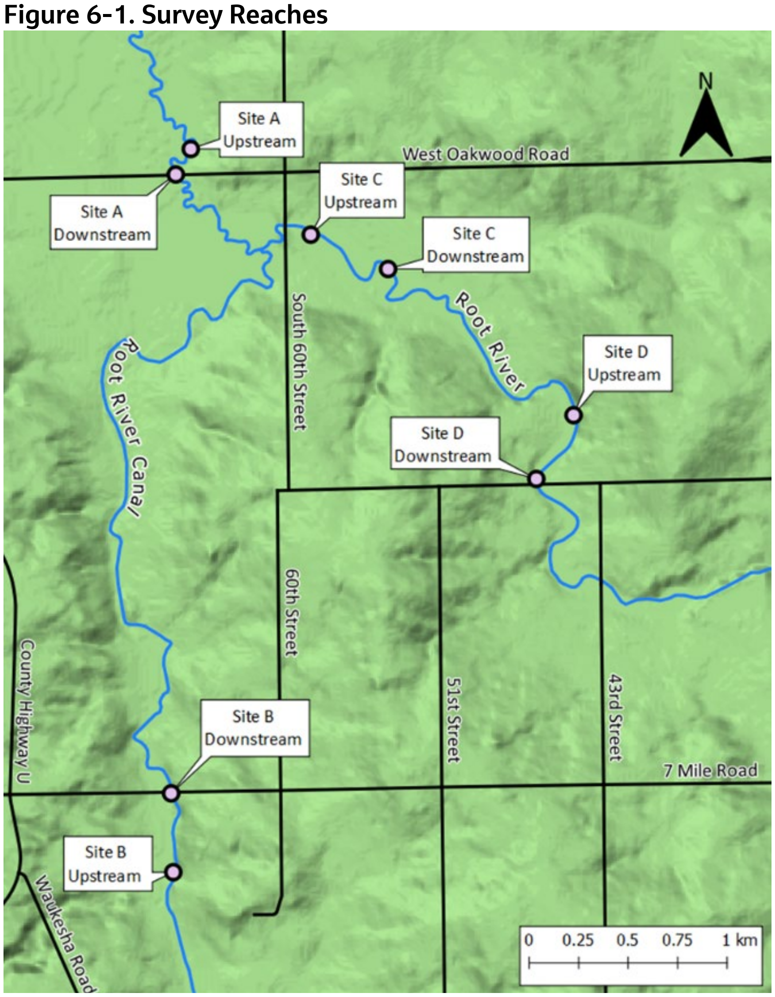
Year	Fish Surveys	
	Summer	Fall
2017	July 27 & 28, Sept. 1	Nov. 7 & 8
2018	July 9 & 10	Nov. 13 & 14

Year	Fish Surveys	
	Summer	Fall
2019	July 26 & 27	Nov. 8 & 9
2020	Aug. 7 & 8	Nov. 5 & 7
2021	July 20 & 22	Nov. 4 & 6
2022	July 22 & 23	Nov. 10 & 11
2023	July 20 & 21	n/a

n/a = not applicable because survey event was not within pre-return flow conditions.

The sampling reaches were established in 2017 and repeated through 2023 (Figure 6-1). Reach lengths differed for each location in proportion to the stream width. Although water levels, and therefore stream widths, differed in 2022 compared to 2017, 2018, 2019, 2020, and 2021, the transects established in 2017 were resampled in 2022 for consistent comparisons.

Figure 6-1. Survey Reaches



6.1 Pre-Diversion Habitat and Biological Data

A summary of habitat and biological data during the pre-diversion period for Sites A through D is described in this section.

6.1.1 Fish Community

Fish sampling was conducted in accordance with the Standard Operating Procedure for the Collection, Identification, and Enumeration of Fishes for the Pre-Return Flow Root River Data Collection Plan (CH2M 2017). Captured fish were identified in the field, counted, and released, and four statistics were calculated at each sampling location from 2017 through 2023: Catch Per Unit Effort (CPUE), Shannon Diversity, Index of Biotic Integrity for Warm Water Fish Communities (Warm F-IBI), and Index of Biotic Integrity for Cool-Warm Water Fish Communities (Cool-Warm F-IBI). Data from these four statistical analyses are displayed as summer (July, August, and September sampling dates) and fall (November sampling dates) for comparison of seasonal differences. No threatened, endangered, or special-concern species were encountered at any of these locations.

CPUE is the number of fish caught per hour of sampling. CPUE provides information on the overall density of fish in the river. Fish exhibit spatial and temporal variations in their distribution and activity; therefore, CPUE may vary widely. The CPUE during the summer and fall surveys are shown on Figures 6-2 and 6-3.

Figure 6-2. Summer Fish Survey Catch Per Unit Effort

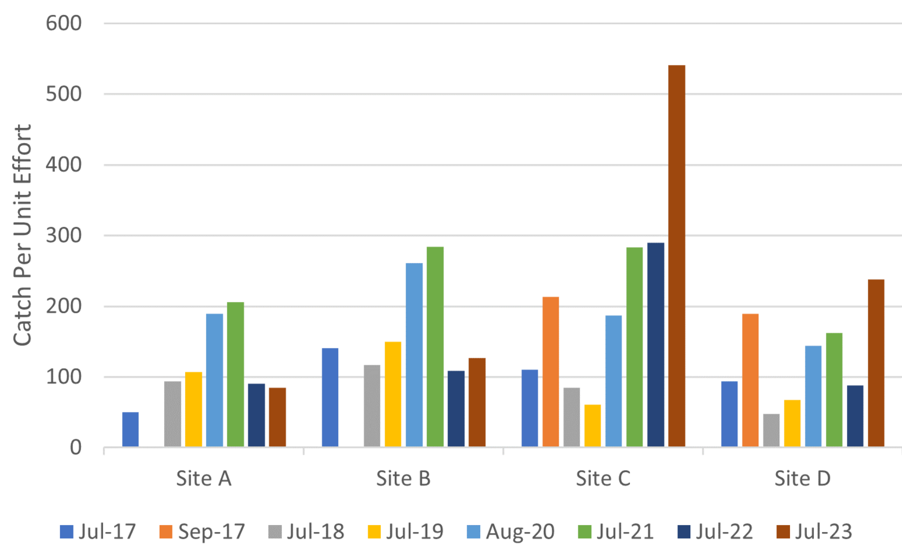
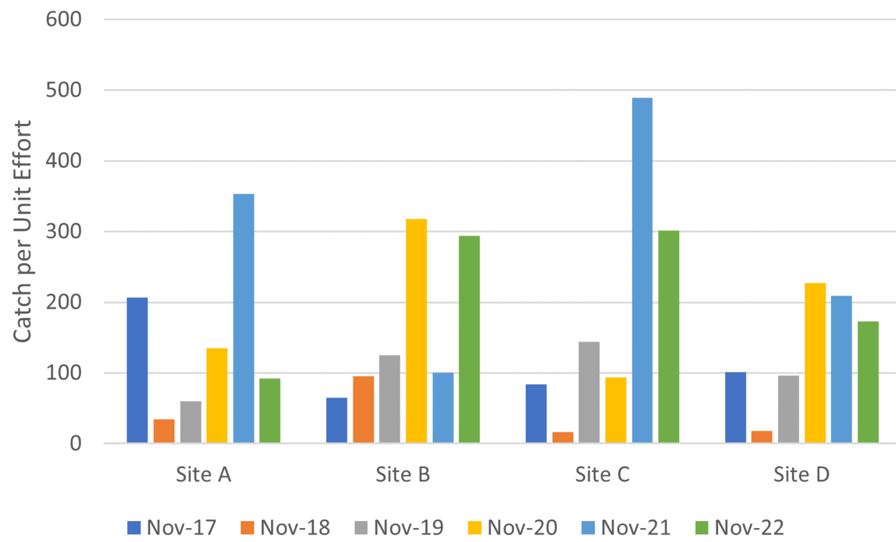


Figure 6-3. Fall Fish Survey Catch Per Unit Effort

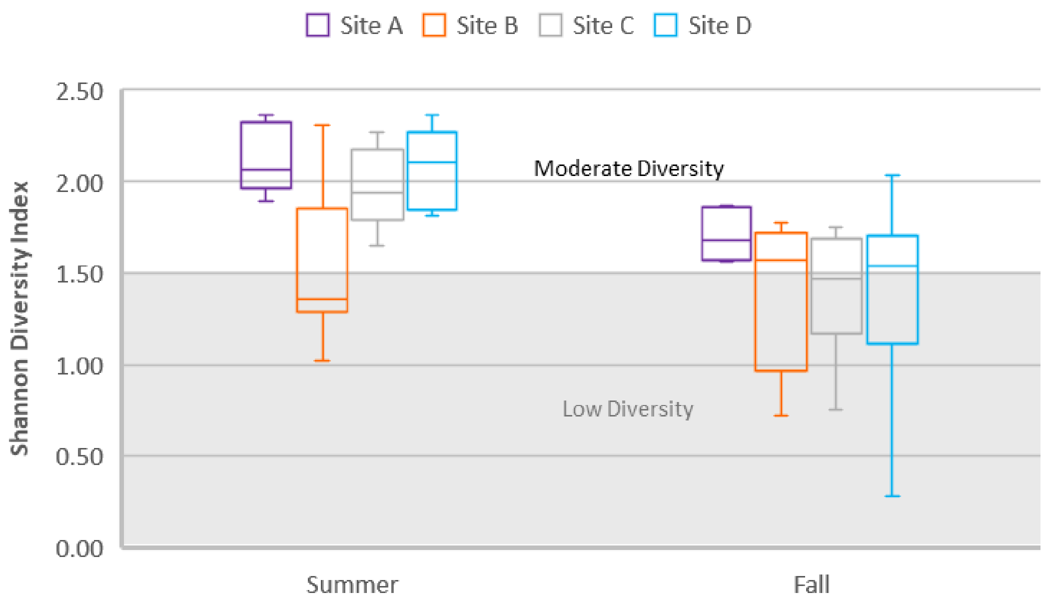


Key Takeaways:

- The CPUE for the summer surveys showed similar trends across all sites, except Sites C and D had their highest CPUE in 2023.
- There is large, but not unexpected, variability in CPUE over time and between seasons possibly from natural variation in recruitment, growth, and mortality.

Shannon Diversity provides a way to combine and compare both the richness (number of species present) and evenness (number of individuals per species) of species in a community. This provides a measure of diversity that can be used to compare communities, habitats, or locations regarding how many individuals of how many species are present. The Shannon Diversity typically ranges from 0 to 3.5, where values from 0 to 1.5 would indicate low diversity, values from 1.51 to 2.5 indicate moderate diversity, and values above 2.51 indicate high diversity. Figure 6-4 shows Shannon Diversity values across summer (July, August, and September) and fall (November) sampling events.

Figure 6-4. Shannon Diversity Index – Box and Whisker Plot by Site and Season

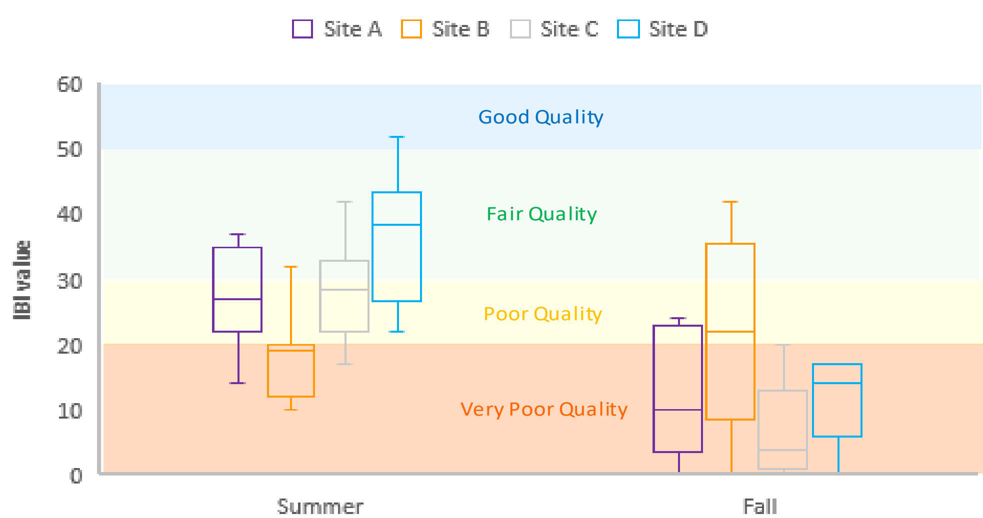


Key Takeaways:

- The Shannon Diversity Index values for the four locations across 7 years of summer sampling consistently indicated moderate levels of species diversity, except for low diversity index values recorded at Site B in August 2020, July 2021, July 2022, and July 2023. Sites A, C, and D had the most consistent Shannon Diversity Index values throughout the sampling events, with little change among the summer samples. Shannon Diversity Index values were most variable at Site B across summer sampling events.
- The Shannon Diversity Index values for the four locations across 6 years of fall sampling have ranged between low and moderate levels of species diversity. Site A has the most consistent scores across all six sampling events, with moderate Shannon Diversity Index values. Sites B, C, and D varied between low and moderate Shannon Diversity values during the fall sampling events.

The IBI is a set of calculations based on the ecological characteristics of the fish present in a given community. The warm water calculation accounts for the number of each species caught; the number of tolerant, hardy species versus the number of intolerant, sensitive species; the number of native versus the number of introduced species; the ecological niches (carnivore, omnivore, herbivore) of the species in the sample; the presence of species that require clean, sediment-free gravel and pebbles to spawn; and the presence of certain species (darters, sunfish, suckers, and salmonids) in the sample. The resulting calculation is a single value indicating the overall quality of the stream habitat, indicating the likelihood of environmental degradation or pollution. The Warm F-IBI score ranges from 0 to 100, with scores of 0 to 19 rated as very poor quality, 20 to 29 rated as poor quality, 30 to 49 rated as fair quality, 50 to 64 rated as good quality, and 65 to 100 rated as excellent quality. Figure 6-5 shows Warm F-IBI values across summer (July, August, and September) and fall (November) sampling events. Note that November 2018 was below the minimum required number of individuals to calculate an IBI score.

Figure 6-5. Index of Biotic Integrity for Warmwater Fish Communities – Box and Whisker Plot by Site and Season

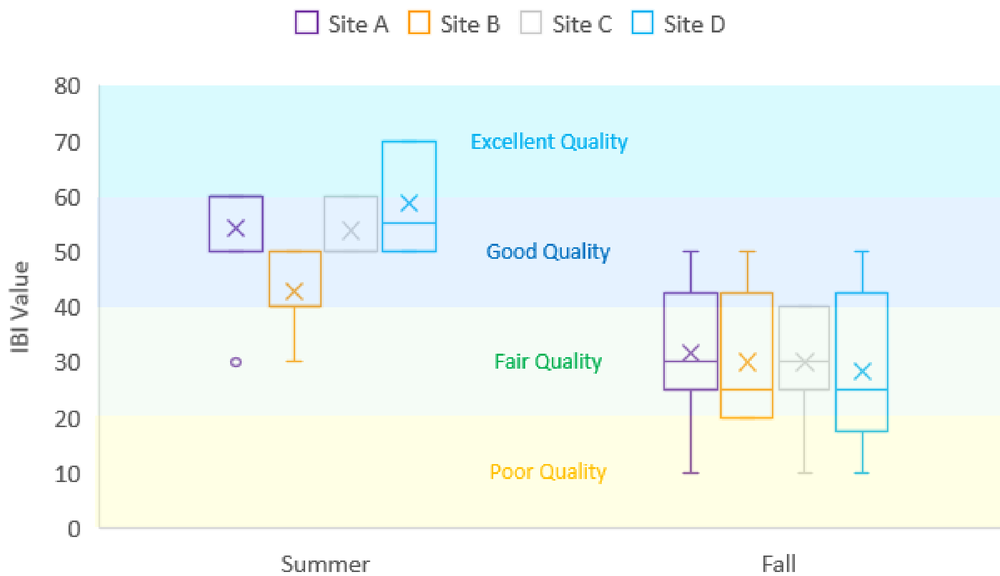


Key Takeaways:

- The Warm F- IBI values in summer surveys typically ranged from very poor to fair quality. Only one location during one sampling event resulted in a good rating.
- The Warm F-IBI values in all November surveys typically ranged from very poor to poor quality, reflecting that in-stream habitats become inhospitable to most fish during the fall, largely because of the cold temperatures these shallow regions of the Root River experience beginning in October and lasting into mid spring.
- Attributed to very warm weather in early November of 2020, Site B had an IBI ranking of fair because of the unexpected number and diversity of fish captured.

The cool-warm water calculation accounts for the number of native minnow species; the number of intolerant species; the percentage of tolerants; the number of benthic invertivore species; and the percentage of omnivores. The resulting calculation is a single value indicating the overall quality of the stream habitat, indicating the likelihood of environmental degradation or pollution. The Cool-Warm F-IBI score ranges from 0 to 100, with scores of 0 to 20 rated as poor quality, 21 to 40 rated as fair quality, 41 to 60 as good quality, and 61 to 100 rated as excellent quality. Figure 6-6 shows Cool-Warm F-IBI values across summer (July, August, and September) and fall (November) sampling events.

Figure 6-6. Index of Biotic Integrity for Cool-Warm Water Fish Communities – Box and Whisker Plot by Site and Season



Key Takeaways:

- The Cool-Warm F-IBI values in summer surveys typically ranged from fair to excellent quality.
- The Cool-Warm F-IBI values in all November surveys typically range from poor to good quality, reflecting that in-stream habitats become inhospitable to most fish during the fall, largely because of cold temperatures in the Root River between October and lasting into mid spring.

6.1.2 Macroinvertebrates

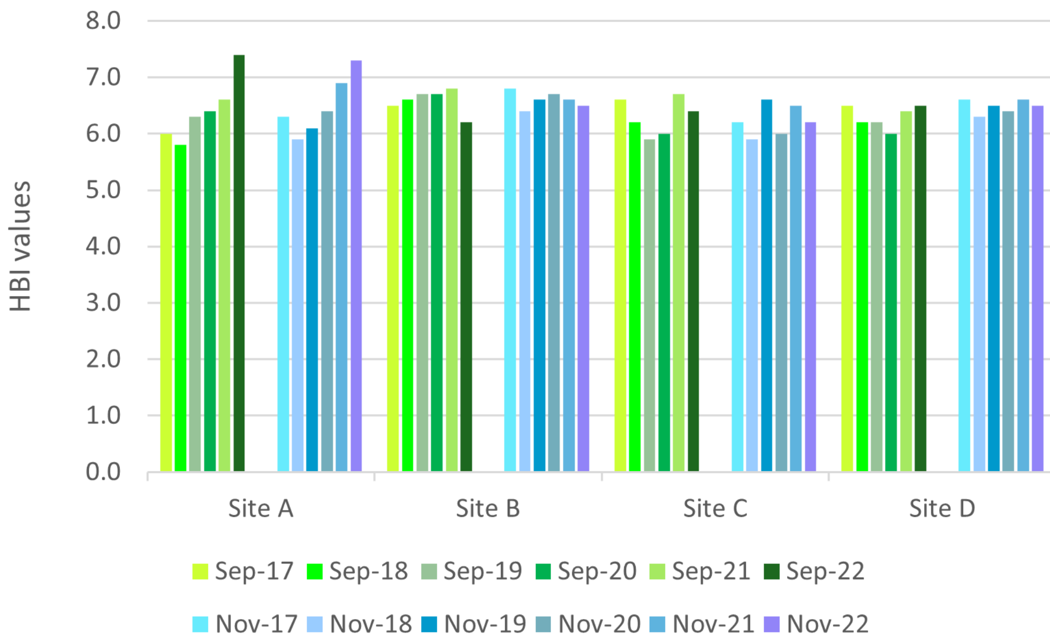
The Hilsenhoff Biotic Index (HBI) value (index ranges from 0 to 10, with lower values indicating higher quality and higher values indicating lower quality) is used to indicate overall water quality – specifically, the presence of organic pollution that would deprive organisms, such as aquatic macroinvertebrates, of dissolved oxygen necessary for cellular respiration. Samples containing more individuals with greater tolerance scores result in greater HBI values, indicating lower water quality and a greater probability of organic pollution. Conversely, samples containing more individuals with lower tolerance scores result in lower HBI values, indicating higher water quality and a smaller probability of organic pollution (Hilsenhoff 1988). Table 6-3 summarizes the range of HBI values correlating to a water quality rating and degree of organic pollution.

Table 6-3. Hilsenhoff Biotic Index Ranges

HBI Value	Water Quality Rating	Degree of Organic Pollution
<3.50	Excellent	None apparent
3.51-4.50	Very Good	Possible slight
4.51-5.50	Good	Some
5.51-6.50	Fair	Fairly significant
6.51-7.50	Fairly Poor	Significant
7.51-8.50	Poor	Very Significant
8.51-10.00	Very Poor	Severe

Macroinvertebrate surveys were conducted during two time periods (early fall and late fall) for six sequential years. Persistent low flows in 2020, 2021, and 2022 may have exacerbated stressful conditions for sensitive taxa at the four locations and may have contributed to lower abundance values in each of these sampling years. Figure 6-7 summarizes the range of HBI values for each sampling site over the past 6 years.

Figure 6-7. Hilsenhoff Biotic Index – Bar Graph by Site and Sampling Date

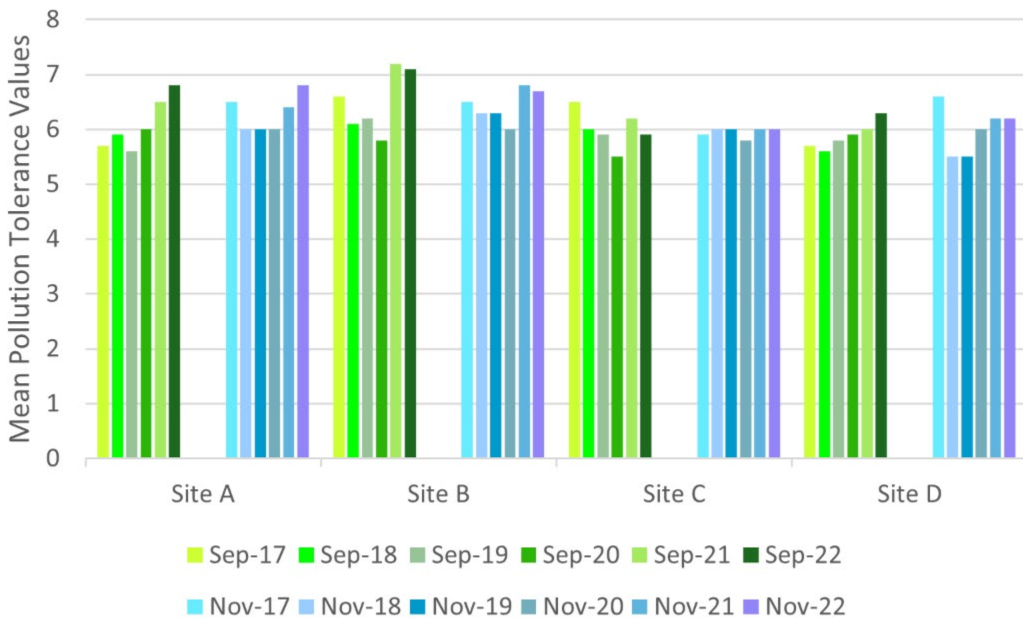


Key Takeaways:

- There is little variability in HBI scores across sites, seasons, and years.
- Since surveys began in 2017, the HBI value at all sites have been classified as either fair or fairly poor in each year or season of sampling.
- Over the past 6 years, HBI designations have consistently indicated that these sites experience impacts from organic pollution.

The mean pollution tolerance value (MPTV) represents the average pollution tolerance value for the macroinvertebrates collected in a sample. Low tolerance values are assigned to taxa that are considered sensitive to organic pollution while higher tolerance values are assigned to taxa that are considered tolerant to organic pollution. This metric calculates the average tolerance score for the taxa present in the sample and is complementary to the HBI because both measures use the same tolerance values. However, the MPTV is not influenced by macroinvertebrate abundance. The MPTV has a range from 0 to 10, with lower values indicating lower average pollution tolerance values (fewer high tolerance value taxa or more low tolerance value taxa) and higher values indicating higher average pollution tolerance values (fewer low tolerance value taxa or more high tolerance value taxa). Figure 6-8 summarizes the range of MPTV for each sampling site over the past 6 years.

Figure 6-8. Mean Pollution Tolerance Value – Bar Graph by Site and Sampling Date



Key Takeaways:

- There is little variability in MPTV scores across sites, seasons, and years.
- Overall, pollution-tolerant taxa have been more common than pollution-sensitive taxa at all four locations for each sampling period.

6.1.3 Habitat

A wadeable stream quantitative habitat evaluation was conducted at each site and over the entire sampling period. Prior to 2021, habitat assessment surveys were conducted in September alongside the aquatic macroinvertebrate sampling. However, the timing of the habitat evaluation changed in 2021 to assess conditions present during summer fish surveys. This change was made to better align with staffing availability and the habitat assessment protocols. No significant changes were observed by the field teams by switching the assessment period to a month earlier in the year.

The same physical and chemical parameters – specifically, pH (S.U.), dissolved oxygen (mg/L), conductivity (mS/cm), water temperature (°C), and turbidity (NTU) – measured during the macroinvertebrate surveys also were assessed during the habitat surveys. Water temperatures were generally warm (22.1 ± 1.1°C) during the habitat surveys, consistent with their classification as warmwater streams. Variation in precipitation events and the associated effects on flow among survey dates may contribute to the minor variations observed in these parameters among sites and sampling dates.

Riparian buffer, substrate, adult gamefish cover, bank erosion data, and algal abundance from the habitat surveys are summarized in the following subsections.

6.1.3.1 Riparian Buffer

Riparian buffer is defined as the length of undisturbed land uses along the transect within 10 meters of the stream (WDNR 2002). Observations during the quantitative habitat evaluation and aerial photographs of the locations confirm that most of the four locations have undisturbed land uses (natural vegetation) within 10 meters of the stream for the length of the reaches surveyed. Exceptions to this may include:

- The right bank of a single transect toward the upstream portion of Site A adjacent to an agricultural field
- The left bank of three transects adjacent to the residential lot in the downstream portion of Site B
- The left and right bank of the two upstream transects of Site C adjacent to agricultural fields

Additionally, the construction of the return flow outfall has altered the riparian area along transect 14 at Site C by replacing 7 feet of the bank with a concrete headwall from the bottom of the river to the top of the bank (about 6 feet tall). The footprint of the outfall structure is small relative to the size of the transect, and the approximately 50 feet of shoreline disturbed during construction was reseeded and stabilized; therefore, in-stream measurements predominantly reflect the natural banks and riparian buffer along this transect. For reference, the return flow outfall structure is shown on Figure 6-9.

Figure 6-9. Return Flow Outfall Structure at the Root River

6.1.3.2 Substrate Data

A significant component of the quantitative habitat evaluation procedure focuses on assessing the percent composition of the substrate. A sediment measurement is taken at four evenly spaced positions along each of the transect lines, with a fifth point added at the deepest point of the channel unless the deepest point has been captured by one of the four evenly spaced positions. Sediment characteristics were estimated for each wadeable transect and summed to calculate the overall proportion of each substrate type present within the reach for each location. **Values reported for silt likely include some proportion of clay because distinguishing between clay and silt is very difficult in the field**. Although flow measurements vary with survey timing and local channel conditions, sediment composition has remained consistent throughout the pre-return flow period. The Root River and Root River Canal sites share similar land use and geology, where these properties contribute to similar substrate characteristics. Overall, the four sites were dominated by fine sediment, including a relatively high percentage of silt, clay, and sand with smaller contributions of larger bed material and moderate amounts of organic material, including the submerged and emergent macrophytes. Organic material continues to be a dynamic component of the substrate at most locations. Over the years, the sites had the following primary composition:

- Site A consisted primarily of silt (ranging from 65.53% to 94.66%) and clay (0 to 20.91%).
- Site B consisted primarily of gravel (6.17% to 29.53%), sand (4.20% to 31.91%), and silt (38.27% to 77.25%).
- Site C consisted primarily of sand (0.90% to 26.66%), silt (51.41% to 93.56%), and organic/detritus (2.14% to 21.00%).
- Site D consisted primarily of gravel (12.10% to 31.92%), sand (0 to 21.01%), silt (26.96% to 83.89%), and organic/detritus (0.14% to 20.73%).

The river bottom was disturbed during construction of the return flow outfall structure where approximately 24 inches of riverbed was replaced with riprap rock. The rock was placed over an approximately 10-foot by 11-foot area to protect the riverbed from scouring with the addition of the return flow. The same as the riparian buffer, this impacted area is small compared to the transect size and, therefore, instream measurements predominantly reflect the natural riverbed along this transect.

6.1.3.3 Cover for Adult Gamefish

Evidence of fish habitat was documented as part of the surveys. Fish habitat was documented at all sites; however, the type of habitat and the extent of the habitat (number of transects) differed at each location. The proportion and distribution of gamefish habitat differs slightly among years, but several types of fish habitat are generally available in each study reach each year. Despite variation among flow conditions and survey timing, woody debris continues to be the dominant fish cover among all sites, while submerged macrophyte beds persist, particularly at Site A, and overhanging banks appear in a few places.

6.1.3.4 Bank Erosion

During the quantitative habitat evaluation, the degree of bank erosion was assessed by measuring the height of exposed soil within 1 meter of the wetted edge on the left and right banks (facing upstream) at each transect. The evaluation of the extent of exposed bank is influenced by water depth and discharge in the channel at the time of the survey. Thus, these instantaneous, empirical values should still be considered estimates of site characteristics. The average exposed bank height measurement for 2022, collected during a low to moderate flow period, was 2.1 meters (± 0.7 meter). This value is most similar to the value of bank erosion measured in 2020, during another low flow period; however, the 2020 surveys were completed in fall rather than summer. The 2022 bank erosion values are slightly higher (indicate more exposed bank) than was recorded in 2021 during the summer season. Overall, the lowest values of average bank erosion still tended to occur with higher flows (2018: 1.0 meter ± 0.7 meter; 2019: 1.4 meters ± 1.1 meters) rather than low flows (2017: 2.1 meters ± 1.1 meters; 2020: 2.1 meters ± 0.4 meter). Table 6-4 summarizes the exposed bank height measured as part of the bank erosion assessment. Spring flooding, the movement of large woody debris, beaver activity, and the reestablishment of vegetation could have contributed to the variation observed in bank erosion measurements throughout the duration of the Pre-Return Flow Root River Collection Plan effort.

6.1.3.5 Algal Abundance

Algal abundance sampling began during the 2021 habitat assessment using an algal viewing bucket. The percentage of algae present was documented at each transect to the nearest 10% at each channel position representing one-fifth of the stream width. Algae generally were observed infrequently. In 2021 Site A had the greatest occurrence of algae across transects and channel positions ranging from 0 to 70%. In 2022, algae were observed at one channel position in one transect at Site A.

Table 6-4. Exposed Bank Heights

Year	Site A			Site B			Site C			Site D		
	Left	Right	Avg.	Left	Right	Avg.	Left	Right	Avg.	Left	Right	Avg.
2017	1.0 ± 0.5 m	1.0 ± 0.6 m	**1.0 m**	1.0 ± 1.1 m	1.5 ± 0.7 m	**1.3 m**	2.9 ± 1.9 m	3.2 ± 2.0 m	**3.1 m**	3.3 ± 2.5 m	2.3 ± 1.4 m	**2.8 m**
2018	0.3 ± 0.4 m	0.5 ± 0.3 m	**0.4 m**	0.6 ± 0.6 m	0.5 ± 0.6 m	**0.5 m**	1.3 ± 0.7 m	0.9 ± 0.6 m	**1.1 m**	1.6 ± 0.6 m	2.4 ± 1.4 m	**2.0 m**
2019	1.2 ± 0.7 m	0.9 ± 0.3 m	**1.1 m**	1.2 ± 0.6 m	0.8 ± 0.7 m	**1.0 m**	1.1 ± 0.8 m	1.6 ± 1.1 m	**1.3 m**	2.1 ± 0.8 m	2.0 ± 0.7 m	**2.0 m**
2020	2.4 ± 1.0 m	3.1 ± 1.3 m	**2.7 m**	2.4 ± 1.0 m	3.1 ± 1.8 m	**2.7 m**	1.8 ± 1.2 m	1.7 ± 0.9 m	**1.8 m**	1.2 ± 0.7 m	1.2 ± 0.5 m	**1.2 m**
2021	0.7 ± 0.4 m	1.4 ± 1.8 m	**1.0 m**	0.7 ± 0.9 m	0.9 ± 0.4 m	**0.8 m**	0.9 ± 0.7 m	0.8 ± 0.8 m	**0.8 m**	2.7 ± 1.5 m	1.7 ± 0.5 m	**2.2 m**
2022	1.0 ± 0.6 m	1.0 ± 0.7 m	**1.0 m**	0.8 ± 0.8 m	2.1 ± 2.7 m	**1.4 m**	2.7 ± 1.5 m	2.4 ± 1.2 m	**2.5 m**	3.5 ± 1.6 m	3.2 ± 1.7 m	**3.4 m**

6.1.4 Additional Data Collection

The previous fish and macroinvertebrate data summary included indices and common metrics for establishing pre-diversion conditions between 2017 and 2023. Additional data were collected as part of the fish and macroinvertebrate data collection activities where these data may be compared to post-diversion data as part of the assessment of impacts from the return flow. The additional data included:

Fish Community

- Total numbers and percentages of species and individuals captured
- Identification of fish with external deformities, erosions, lesions, and tumors (DELT anomalies)
- Adult individuals of game species (pike, centrarchid bass, and sunfish) were measured for total length before release

Macroinvertebrate

- Taxa abundance
- Taxon richness and ephemera, plecoptera, and trichoptera generic richness
- Diversity (Shannon Diversity Index)
- Evenness
- Percent depositional taxa
- Percent Chironomidae
- Functional feeding groups (percent shredder, scraper, gatherer)
- Percent Macrocrustacea (percent isopod and percent amphipod)
- Channel and basin data
- Flow data

6.1.5 Diatom Survey

The WDNR collected pre-diversion diatom data within the Root River. It was not available for inclusion in this report but is anticipated to be included in future-year summaries.

6.2 Post-Diversion Habitat and Biological Data

This report includes pre-diversion conditions. Post-diversion Root River habitat and biological data will be summarized in future annual reports to address the following topics:

- Changes in the river macroinvertebrate, fish, or diatom community (as provided by the WDNR) upstream or downstream of return flow as compared to pre-return flow conditions
- Spatial extent of the changes caused by return flow
- Assessment of the changes as natural variability, an indication of potential upstream watershed impacts, or an indication of changes resulting from return flow

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